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FOREWORD

1. PURPOSE

The purpose of MCWP 3-17.4, Engineer Reconnaissance, is to provide specific techniques and procedures for Marine Corps reconnaissance forces and engineers in particular, to conduct successful engineer related data collection, recording, and reporting procedures. This publication will also alert MAGTF and element staffs to the types of information gathered during engineer reconnaissance.

2. SCOPE

Reconnaissance is an essential, continuous function conducted by the commander to collect information about the enemy and the battlespace. The mobility of the Marine Air Ground Task Force (MAGTF), relative to that of the enemy, is intregal to maneuver warfare. Engineer reconnaissance of the battlespace provides important information to the planners and decision makers of the MAGTF and its elements. The role of engineers in reconnaissance and Intelligence Preparation of the Battlespace supports the commander's decision process in determining a course of action.

Marine Corps Warfighting Publication 3-17.4 provides field techniques, formulas, and forms information, to be used in engineer reconnaissance ashore. These portions of the publication can be used in conjunction with MCRP 3-17B, Engineer Forms and Reports, to produce the data necessary for commanders to plan and execute their missions.

To successfully plan and execute an engineer oriented reconnaissance, commanders should also review the information in MCWP 2-15.3, Ground Reconnaissance, for detailed planning guidance and MCWP 3-11.6, Scouting and Patrolling, for small unit tactical training.

3. CERTIFICATION

Reviewed and approved this date.

BY DIRECTION OF THE COMMANDANT OF THE MARINE CORPS

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Chapter 1
Mission and Organization

1001. Introduction

Combat power is generated by combining command and control, maneuver, fires, intelligence, logistics, and force protection within a sound plan and then aggressively, violently, and flexibly executing the plan to defeat and enemy. The key to using combat power effectively is gathering information about the enemy and battlespace through reconnaissance. Reconnaissance provides current information that helps a commander's planning and decision making during operations. Accurate and timely reconnaissance enhances maneuver, fires, and force protection. Engineer specific reconnaissance gathers data for intelligence that the Marine Air Ground Task Force (MAGTF) commander can use to increase tempo by negating the effects of enemy countermobility operations and to find and maintain quality main supply routes (MSR) to support the elements of the MAGTF. The data can be used to magnify the effects of fire by employing countermobility operations against the enemy, reducing their tempo. It also provides the information needed by the commander to deploy his forces advantageously through employing the force multiplier effects of survivability operations to protect MAGTF assets.

Reconnaissance is the first step in intelligence, the collection of information. The use of engineers in the reconnaissance and intelligence process can improve collection of data and contribute to the processing, exploitation, evaluation, integration, analysis, and interpretation of the available information. Engineer reconnaissance contributes to the first objective of intelligence, reducing uncertainty by providing accurate, timely, and relevant knowledge about the threat and battlespace.

1002. Missions

The primary mission of engineer reconnaissance is to collect engineering oriented tactical and technical information for the supported unit or MAGTF. The engineers, and necessitated by circumstance non-engineers, must be able to perform this mission day or night and in various terrains and environments.

An engineer reconnaissance may be conducted in a hostile environment (e.g., at the FEBA or in enemy controlled areas) in an effort to --

- Collect information about the enemy's location of obstacles, engineering capabilities, and the terrain within the area of operations (AO). Engineers attempt to gather information without detection by the enemy.
- Conduct limited marking of obstacles, routes, and demolition work (if specified in the mission order).
- Conduct limited reduction of obstacles in conjunction with maneuver units (if specified in the mission order).

An engineer reconnaissance may also be conducted in a more benign environment (e.g., rear of the FEBA or in friendly controlled areas) in an effort to --

Collect information about the terrain and MSRs.
Locate additional bypasses of terrain features or obstacles.
Locate suitable locations for encampments, logistics storage areas, and engineering materials (e.g., lumber, concrete, water, etc.).

Low threat environment engineer reconnaissance of a point, area, or route is normally more technically oriented and detailed and may or may not be a combined-arms effort. Engineers may work without augmentation from non-engineer units.

1003. Organization

An unit tasked to perform an engineer reconnaissance mission can organize its reconnaissance element in three ways:

a. Maneuver element/reconnaissance element only member team for deep zone missions. Engineer units should provide training, equipment, and support to the reconnaissance personnel to enable them to collect the necessary data. Restricting engineers from direct participation in these missions is largely determined by the insertion/extraction techniques to be employed or other specialized tactical training that the engineers lack which would compromise the safety and success of the mission;

b. Maneuver element/reconnaissance element members augmented with engineers. These types of teams are normally used for reconnaissance missions just forward or immediately to the rear of the Forward Edge of the Battle Area (FEBA). Specialized tactical training would not normally be required to operate in this part of the Area of Operations (AO). If engineers are to operate with another units reconnaissance elements, the engineer team members should be task organized with equipment compatible with the supported units reconnaissance element. The team members may use their own equipment or those of the supported unit depending upon its equipment, organization, command and control (C^2) structure, and enemy situation;

c. Wholly comprised of engineer personnel. This is most suitable for rear areas of the AO or benign areas where threats are low and where security threats are low. However, when circumstance allows engineers should be directly involved with all reconnaissance missions which require the collection of engineer related data. The experience and expertise they contribute through first hand observation and assessment obstacles, terrain, and enemy engineer capabilities can increase the quality and reliability of the data collected.

1004. Characteristics, Capabilities, and Limitations

The team members capabilities and limitations must be considered when they are employed. The most important limitation is that engineer units do not have dedicated reconnaissance personnel and equipment. When they are employed in reconnaissance missions the personnel and equipment is not available for other engineering missions.

When commanders plan an engineer reconnaissance mission, they should consider the following when determining the units to be tasked and the composition of the engineer reconnaissance team members:

<u>General Characteristics of Engineer Reconnaissance Missions</u>

Characteristics of typical engineer reconnaissance personnel and equipment include the following:

- An engineer reconnaissance usually depends on both the parent engineer unit and the supported unit for combat support and combat service support;
- At least two engineers;
- Specialized equipment (e.g., surveyors set, mine detectors, minefield marking kit, range finders, demolition, etc.);
- Motor transport (especially for route reconnaissance);
- Additional engineers with special training to accomplish specific tasks or gather specific data.

<u>Capabilities Normally Required for Engineer Reconnaissance Missions</u>

A reconnaissance mission, augmented with engineers, will normally have the following capabilities:

- Increases the supported unit's capabilities to detect and evaluate complex mine and wire obstacle systems, gather data on enemy engineer activities, and evaluate mobility concerns along a route;
- Provide more technical information concerning obstacles and minefields that may require Explosive Ordnance Disposal support;
- Conduct an analysis of what assets will be needed to reduce obstacles;
- Evaluating bypasses of obstacles and if included in the mission orders marking the bypasses or obstacles;
- Provide detailed technical information on routes and specific information on bridges, tunnels, fords, and ferries along a route;
- Gathering information on enemy engineer equipment capabilities;
- At as guides for the Breaching Task Force, if necessary;
- Assist the supported units gathering of non-engineering enemy information.

<u>Limitations and Effects on an Engineer Reconnaissance Mission</u>

A reconnaissance mission has the following limitations:

Complete engineering data is time consuming to collect-reconnaissance activities will require more time, unless the size of areas to be reconnoitered, or the number or distances of routes to be reconnoitered is reduced;
Engineers on reconnaissance missions have limited obstacle creation and reduction capabilities;
Engineer units do not have dedicated personnel and equipment to conduct engineer reconnaissance operations. Engineers must train and rehearse extensively with the units supported to ensure that all Marines understand the reconnaissance training, tactics, and procedures to be used during the mission.

Enhancing Engineer Reconnaissance With Transportation Assets

Ground Transportation: Use of motor transport reduces travel time to and from the area or point to be evaluated. Reduced travel time means more time is available to gather the detailed data required of most engineering reconnaissance missions. This is especially true for route reconnaissance when movement between points of concern along the route allows more time to stop and evaluate suspected or known areas of interest. Engineer reconnaissance of a route does not normally require detailed inspection of every segment. Soil or compaction tests, inspection of battle damage, or damage caused by natural occurrences (e.g., flooding) may only require stops along the route. Minus these requirements or concerns, route reconnaissance often allows rapid transit between points of concern.

Air Transportation: The collection of data inherent to engineer reconnaissance (e.g., bridges) is very time consuming. Air transportation of the reconnaissance personnel allows more time on site to collect the necessary data. Also, air transportation can be used to perform preliminary surveys of large areas and aid in identifying locations that may require detailed engineer reconnaissance on the ground or to narrow down prospective sites suitable for engineer operations (e.g., bridging, ferries, emplacement of obstacles, etc.).

1005. Command and Support Relationships

Task organization for engineer reconnaissance is METT-T dependent and is used to establish command relationships for the forces involved. The MAGTF possesses organic engineer units capable of performing engineer reconnaissance.

Determining the appropriate relationship to support the mission is based on which of the three command and support relationships provides the most efficient use of engineer assets:

General Support-That support which is given to the supported force as a whole and not to any particular subdivision thereof;

Direct Support-A mission requiring a force to support another specific force and authorizing it to answer directly the supported force's request for assistance;

Attached-The placement of units or personnel in an organization where such placement is relatively temporary.

Command Element (CE)

The CE possesses no organic engineer capabilities. The CE may have an engineer special staff officer assigned, however, the engineer staff officer or staff members are often composed of the commanders and staff members from one or more of the engineer units assigned to the MAGTF.

Ground Combat Element (GCE)

The GCE possesses an organic engineer capability. A Combat Engineer Battalion (CEB) or a subordinate element of the CEB is present in the GCE. The CEB normally provides direct support to elements within the GCE and also retains assets that remain in general support. The general support element within the CEB or subordinate retains combat engineer capabilities and the preponderance of equipment and specialized personnel. If the engineer capability within the GCE is limited all assets may remain in general support except as required by the mission.

The CEB or subordinate element is the primary source for engineer reconnaissance support at and forward of the FEBA and in the immediate rear of the FEBA.

Air Combat Element (ACE)

The ACE possesses an organic engineer capability. A Marine Wing Support Group (MWSG) or subordinate element of the MWSG is present in the ACE. The MWSG is in general support to the Marine Air Wing (MAW). The MWSG possesses one or more Marine Wing Support Squadrons (MWSS) which contain the engineers and engineer equipment. Each MWSS or their detachments provide direct support to the Marine Air Groups or squadrons. This is dependent upon the ACE's composition and mission.

The MWSG/MWSS or detachments are the primary source of engineers for engineer reconnaissance in the vicinity of air fields or to support other engineer reconnaissance requirements of the ACE.

Combat Service Support Element (CSSE)

The CSSE possesses organic engineer capability. An Engineer Support Battalion (ESB) or subordinate element is present in the CSSE. The CSSE is in general support to the MAGTF.

The ESB or subordinate element is the primary source for engineer reconnaissance support in the rear area of the AO.

Attached

Reconnaissance missions conducted by non-engineer units requiring engineer participation would normally be of limited duration and would not require an attachment of engineers to complete.

Attaching engineers will be driven by C^2 and other operational considerations. Examples of when this might be necessary would be to prepare for a deliberate breach, mobile CSSD, reconnaissance of expeditionary airfield sites, or any situation where the reconnaissance mission requirement is given to a non-engineer unit and the mission is expected to be of long duration, remote from the parent engineer unit, or require frequent engineer participation. The ACE, CSSE, and GCE are capable of forming engineer detachments which can be attached to units tasked with engineer reconnaissance missions.

Chapter 2

Engineer Reconnaissance Planning

Data collected through engineer reconnaissance should be treated the same as information collected by all other types of reconnaissance. This information must be conveyed to the supported unit commander along with the other data collected. It could be critical for the intelligence estimates being formed by the supported unit's staff.

The senior engineer assigned to the engineer reconnaissance mission must clearly understand the mission and commander's guidance and know what is expected of his engineers during the reconnaissance. Also, he must be given the areas or points of concern to be reconnoitered and know what information he is expected to gather. The engineers must be focused on the obstacles, mobility, or enemy engineer assets. However, the engineers should be prepared to report on non-engineer specific information as part of the reconnaissance. The G2/S2 must provide the engineers with all of the available engineer oriented information concerning mines, obstacles, etc. they may encounter during the mission.

The engineers must be a part of the supported unit's reconnaissance plan at the earliest stages. Reconnaissance is a vital part of the Intelligence Cycle. Early and continuous collection and analysis of engineer reconnaissance data provides for a more comprehensive understanding of the battlespace and can allow for a broader range of Course of Actions (COA). The MAGTF and subordinate commanders should use the following twelve fundamentals of ground reconnaissance for engineers as with any other ground reconnaissance mission:

Supports the commander's intent;
Provides the most reliable source of information;
Assets are best employed early to support courses of action;
Assets are best employed in general support;
Requires adequate time for detailed planning and preparation;
Requires adequate time for execution;
Must be integrated into overall intelligence operations plan;
Integrates reconnaissance and intelligence collection planning;
Orient on the enemy to gain and maintain contact (engineering reconnaissance often does <u>not</u> require long term contact with enemy forces);
The best asset should be employed for each specific task;
Relies on stealth, maneuver, and timely, accurate reporting;
Evolving tactical situation requires flexible reporting to the supported command.

(See MCWP 2-15.3, Ground Reconnaissance Operations, for additional explanation).

2001. Intelligence Preparation of the Battlespace (IPB)

Intelligence Preparation of the Battlespace is a systematic approach to analyzing the enemy, the weather, and the terrain in a specific geographic area. It integrates enemy doctrine with the weather and terrain as they relate to the mission and the specific battlespace environment. This is done to determine and evaluate enemy capabilities, vulnerabilities, and probable courses of action (COA). Table 2-1 summarizes the engineer's participation in the IPB process.

Table 2-1 Engineer Input To The IPB

Engineer Input	**IPB Steps**	**Outpu**
Terrain data Available threat engineer assets	Define the battlespace environment	
Terrain analysis (KOCOA)	Describe the battlespace's effects	MCOO
Threat engineer doctrine Engineer HVTs Threat engineer capabilities	Evaluate the threat	Intelligence estima
Threat engineer support to each COA	Determine threat COAs	SITEMP Listing of HVT Identify NAIs Event template

As the threat estimate process develops, a number of critical locations will become apparent (key terrain and man-made features such as bridges and fords). These areas are important because significant events are likely to occur there. It is within these areas that objectives are likely to be chosen or targets will appear. These areas are designated as NAIs. NAIs must be observed to be effective. Therefore, the number and location of NAIs designated is tied to the unit's ability to observe them.

NAIs may also be developed during the decision-making process. NAIs developed during the IPB and decision-making processes are prioritized, and reconnaissance assets are tasked to collect information to support the commander's information requirements (IR). Engineer reconnaissance should be used for those NAIs requiring engineer expertise.

In the offense, a maneuver unit's G2/S2, with assistance from engineers on the unit's staff and/or from engineer unit commander(s), will determine likely enemy actions, how enemy direct-fire systems and obstacles are arrayed, and what counterattack routes the enemy is likely to take. The G2/S2 and engineers on the unit's staff and/or from engineer unit commander(s) will also provide input on enemy scatterable-mine capability and where the mines may be employed, based on how the enemy is predicted to fight. The G2/S2 and engineers on the unit's staff and/or from engineer unit commander(s) provide any available information about existing obstacles on the avenue of approach or mobility corridor. The G2/S2 and the engineer unit(s) commander(s) will incorporate this information into their IPB.

In the offense, primary focus of the engineer reconnaissance should be on enemy emplaced obstacles. This includes but is not limited to:

- Obstacle location;
- Obstacle orientation;
- The presence of wire;
- Gaps and bypasses;
- Minefield composition and emplacement;
- Specific mine types;
- The location of enemy direct-fire weapons.

In the defense, a maneuver unit's G2/S2, with the engineers on the unit's staff and/or from engineer unit commander(s) assistance, conducts a terrain analysis to determine an enemy's avenues of approach. The MAGTF G2/S2 and maneuver unit's G2/S2 work closely with the engineers on the unit's staff and/or from engineer unit commander(s) to provide input on enemy engineer assets, enemy engineer COAs, and to template the enemy's obstacle use. An engineer reconnaissance may be focused on:

- Obtaining information about planned routes to be used during counterattacks, repositioning, or retrograde operations;
- Augmenting reconnaissance to identify enemy engineer equipment and activity;
- Observe locations where friendly forces will emplace scatterable-mine fields to provide information on the minefield's effectiveness and to call fires on enemy units;
- Observing NAIs where the enemy is expected to employ scatterable-mine.

2002. Engineer Reconnaissance Planning

The G2/S2, in coordination with the G3/S3, prepares a detailed Reconnaissance and Surveillance Plan that graphically depicts where and when reconnaissance missions will be executed to look for enemy activity. The Reconnaissance and Surveillance Plan must contain specific tasks and priorities for all Reconnaissance and Surveillance Plan elements. The G2/S2 designates NAIs for the engineer reconnaissance. The G3/S3 maintains overall OPCON of the Reconnaissance and Surveillance Plan; however, the G2/S2 plans and monitors the Reconnaissance and Surveillance Plan. The reconnaissance leader, whether or not an engineer, further refines the reconnaissance plan to include proper patrol and reconnaissance TTP.

The supported unit's G2/S2 should brief the reconnaissance leader on the disposition of friendly forces and the unit's scheme of maneuver. The G2/S2 provides the reconnaissance leader with the current and projected Reconnaissance and Surveillance Plan and operational graphics. It is important for the reconnaissance leader to be familiar with the commander's intent as it applies to the particular NAI and mission assigned. The G2/S2 of the maneuver unit and engineer unit commander should plan to employ the same reconnaissance team members throughout the NAI's mission. This enhances team performance and allows the engineers to develop comprehensive observations vice piecemeal data. The G2/S2 should provide guidance on when to report, what actions to take on enemy contact, and what Combat Support and Combat Service Support assets are available. The engineer staff, working with the G2/S2, ensures that all known specifics concerning obstacles, terrain, and enemy engineer assets that may be encountered are included in the mission briefing. As with any patrol or reconnaissance operation the MAGTF staff, supported unit, and engineer unit should assist the reconnaissance leader by coordinating with other friendly units in or adjacent to the AO where the reconnaissance mission will take place. See MCWP 2-15.3, Ground Reconnaissance for more information concerning the conduct of reconnaissance operations.

Once at the designated site(s) the engineer reconnaissance team members should confirm or deny the information provided by the G2/S2. The reconnaissance members:

- Look for engineer-specific information about the obstacle (e.g., composition, mines, etc.);
- Conduct an analysis of the terrain and soil composition to determine whether mine-clearing blades and other engineering equipment can be employed successfully;
- Reconnoiters for bypasses, gaps, and breach sites.

The information obtained during the reconnaissance must be relayed quickly to the G2/S2 based on the guidelines provided during the mission briefing.

Engineers are active participants in ground reconnaissance that provides both maneuver and unit commanders with information about the terrain, enemy engineer activity, obstacles, and weather effects within an AO. A tactical engineer reconnaissance normally takes place in a hostile environment. A tactical reconnaissance is conducted to gain information forward of friendly lines or to provide current, accurate information about terrain, resources, obstacles, and the enemy within a specified AO. During a reconnaissance, engineers may assist maneuver units in reconning the terrain to determine its effects on maneuverability and the enemy situation. When the enemy is located, the engineers help determine his strengths and weaknesses with a focus on enemy engineer activities and obstacles. A reconnaissance team provides the information necessary to allow ground combat forces to maneuver against the enemy, attack him where he most vulnerable, and apply overwhelming fire and mass to destroy or otherwise defeat him. Engineer reconnaissance can provide the additional information needed to allow combat forces the freedom to maneuver and knowledge of enemy obstacles and their likely impact. This chapter provides basic information on the three types of engineer reconnaissance missions. Detailed instruction for conducting ground reconnaissance and patrolling operations can be found in MCWP 2-15.3, Ground Reconnaissance, and MCWP 3-11.3, Scouting and Patrolling, respectively.

2003. Purpose and Fundamentals

Engineers should consider all engineer reconnaissance missions to be tactical in nature, even in areas considered safe. Engineer reconnaissance information provides ground combat forces with the opportunity to maneuver to their objectives rapidly. There are three types of engineer reconnaissance: route, zone, and area. These are normally technical in nature. Technical reconnaissance involves gathering detailed data that requires close, on-site observations, and measurements. Examples of technical reconnaissance include precise measurements of metal girders on a bridge, the measurements for a tunnel, the type of mines in a mine field, soil conditions, etc. Technical reconnaissance normally takes place during any of the three types of engineer reconnaissance missions.

2004. Types of Engineer Reconnaissance

Reconnaissance techniques achieve a balance between the acceptable level of risk and the security necessary to ensure mission accomplishment. This balance is often a tradeoff between speed and security. The faster the reconnaissance, the more risk a reconnaissance team accepts and the less detailed reconnaissance it conducts.

To reduce vulnerability on the battlefield, engineers should rehearse reconnaissance TTP in detail and, when working with a supported unit, the training should include the supported unit's reconnaissance personnel. The knowledge and rehearsal of reconnaissance techniques, combined with an understanding of a mission's particular METT-T requirements, allow the engineer reconnaissance leader to mix and choose the methods that maximize security and mission accomplishment.

Route Reconnaissance

A form of reconnaissance focused along a specific line of communications, such as a road, railway, or waterway, to provide new or updated information on route conditions and activities along the route. When the commander wants to use a specific route, a maneuver unit, normally supported by engineers, conducts a route reconnaissance to gain detailed information about a specific route and the adjacent terrain that the enemy could use to interdict friendly movement. This ensures the commander has the latest information about the route's current condition, and the existence of obstacles and observed problems and potential problems (e.g., low areas subject to flooding, likely ambush sites, etc.). It also is intended to confirm the route's suitability for the types and numbers of vehicles to traverse it.

Zone Reconnaissance

A direct effort to obtain detailed information concerning all routes, obstacles (to include chemical or radiological contamination), terrain, and enemy forces within a zone defined by boundaries. A zone reconnaissance normally is assigned when the enemy situation is vague or when information concerning cross-country trafficability is desired. Maneuver units, normally with engineer assistance, conduct zone reconnaissance missions. The zone is a smaller, defined area within the AO. Commanders normally assign a zone reconnaissance mission when they need information prior to traversing the zone with maneuver units or equipment. Engineers produce information about routes, cross-country trafficability, terrain, and obstacles. If enemy engineering activities are known or suspected the engineer reconnaissance effort tries to determine the capabilities and activities of the enemy engineers. A zone reconnaissance is often most suited for gaining information about an AO where long term operations are anticipated or when information for possible future uses are required. Depending upon how much technical reconnaissance activity will be performed in the zone, commanders should anticipate that the engineer reconnaissance will be more time consuming than a typical non-engineering reconnaissance of the same size zone.

Area Reconnaissance

A form of reconnaissance operations that is a directed effort to obtain detailed information concerning the terrain or enemy activity within a prescribed area, such as a town, ridge-line, woods, or other feature critical to operations. An area reconnaissance could be made of a single point, such as a bridge or installation. A maneuver unit, normally augmented by engineers, normally conducts an area reconnaissance to support operational plans with specific information about point or localized sites, targets, or objectives.

Critical Engineer Reconnaissance Tasks (See Table 2-1)

Types of Engineer Ground Reconnaissance
R=Route, A=Area, Z=Zone

Table 2-1. Engineer Reconnaissance Critical Tasks

R, A	Determine the route's trafficability (see Chapter ?)
R	Reconning built-up areas along the route (includes identifying bypasses, construction supplies and equipment, ambush sites, evidence of booby traps, and suitable sites for C2/CSS facilities)
R	Reconning lateral routes to the limit of direct fire range
R	Inspecting and classifying bridges on the route
R	Locating fords or crossing sites near bridges on the route (includes determining fordability and locating nearby bypasses that can support combat and CSS units, marking bridge classification and bypasses, and being prepared to provide guides)
R, Z, A	Inspecting and classifying overpasses, underpasses, and culverts
R, Z, A	Locating obstacles and reduction requirements
R, Z, A	Locating bypasses around obstacles, contaminated areas, and alternatives for suspected trouble areas (e.g., low points susceptible to flooding)
Z, A	Reconning key terrain
Z, A	Reconning built-up areas in the area/zone
Z, A	Inspecting and classifying bridges in the area/zone
A	Locating fords or crossing sites near bridges (includes determining fordability and locating nearby bypasses that can support combat and CSS units, marking bridge classification and bypasses, and being prepared to provide guides)
A	Locating fords or crossing sites near bridges in the area (includes determining fordability and locating nearby bypasses that can support combat and CSS units, marking bridge classification and bypasses, and being prepared to provide guides)

R, Z, A	Reporting the reconnaissance information

2005. Preparing Engineers for Tactical Reconnaissance

To successfully conduct engineer reconnaissance, either as a reconnaissance composed only of engineers or integrated with a non-engineer supported unit, engineers must be familiar with the engineering requirements discussed in Chapters 4 and 5, and with the reconnaissance and patrolling skills required for security and small unit tactical employment. The current Marine Corps engineer structure does not contain personnel and equipment dedicated to reconnaissance missions. Successful employment of engineers in a reconnaissance role is the result of the engineering staffs and the engineer Marines to be trained to accomplish specific missions as dictated by the mission orders and to include sufficient TTP I the units' SOPs and training prior to deployments.

Regardless of which engineer units provide the Marines for the mission, the units will have to dedicate training to developing personnel capable of successfully participating in reconnaissance missions:

- Understanding how to apply the fundamentals of patrolling and reconnaissance operations
- Operating with MAGTF assets and maneuver forces to develop the skills necessary to succeed on the battlefield
- Reporting, calling for fires, first aid, land navigation, demolition, minefield detection, foreign mine recognition, dismounted movement techniques, helicopter insertion/extraction, resupply, communications procedure
- Noise, light, litter discipline, the use of NVDs and camouflage
- Physical training

Support of Obstacle Reduction/Breaching Operations

During engineer reconnaissance missions the reconnaissance team will normally encounter enemy obstacles. It is not a primary task for reconnaissance units to reduce encountered obstacles. Reduction activities can compromise the security of the reconnaissance team, is time consuming, and may require additional personnel and equipment (e.g., demolition, shovels, wire cutters, etc.) that add to the reconnaissance mission support requirements. A commander should consider assigning obstacle reduction tasks to a reconnaissance mission only when the benefits out way security and logistical concerns.

If an engineer reconnaissance mission provides data that compels a commander to conduct a deliberate or hasty breach, the engineers participating in the reconnaissance mission become a valuable asset. They are the primary source for:

- Trafficable routes to the breach sites and aiding determining routes from the far side to the objective

Proposed locations for positioning the Breaching Task Force elements or the maneuver unit's hasty breaching assets (e.g., dispersal sites, cover, and concealment)
Determining the specific breach sites
Locations of the enemy on the near and far sides
Soil and terrain analysis in the breach area
Locating the forward edge of any minefields

Chapter 3

Conducting Engineer Reconnaissance

This chapter describes how to perform the technical aspects of an engineer reconnaissance. Engineer reconnaissance data may require conversion between metric and American Standard measures. Appendix A contains a conversion chart. Detailed explanations of how to use the numerous engineer related forms can be found in MCRP 3-17B, Engineer Forms and Reports. Blanks of the five most common reports used can be found in Appendix B. A summary of common symbols used in the reports can be found in Appendix C. Appendix D, Bridge Classification Factors, contains tables and graphs required to complete a bridge classification assessment.

3001. Route Reconnaissance

Route classification is a tool that helps determine what loads of vehicles can travel along a route and how fast it may travel. After a route is reconned the results are transferred to an overlay for display on a map. During war or military operations other than war (MOOTW), only the necessary and essential facts about a route are gathered as quickly and safely as possible. This information is placed on a route-classification overlay and supplemented by additional reports. During AO reconnaissance detailed route-classification missions are performed to obtain information for future use. Route classification may be conducted throughout the AO, both in the rear areas and forward of the FEBA. The first step in understanding the technical portions of a route reconnaissance is understanding what information is needed to complete a route-classification overlay.

3002. Route-classification Overlay

A route classification overlay depicts a route's entire network of roads, bridge sites, and other major features or points of concern. These items are reconned and the data recorded as support documentation for the route overlay. A route classification gives details on what obstructions will impact the movement of personnel, equipment, and supplies along the route. Engineers are trained and possess special training to conduct route reconnaissance and classification.

As a minimum, the following information will be included on the route classification (see Figure 3-1):

- The route classification formula
- The name, rank, and social security number (SSN) of the person in charge of performing the classification (this is necessary if clarifications or questions concerning the route occur)
- The unit conducting the classification
- The date-time-group (DTG) that the classification was conducted
- The map name, edition, and scale
- Any remarks necessary to ensure complete understanding of the information on the overlay

Figure 3-1. Route Classification Overlay

Route Classification Formula

A route classification must include every alternate road on which movement can be made along the route, all lateral roads intersecting the route out to direct fire weapons range, the types of vehicles that can utilize the route, and the traffic load specific portions of the route can handle (this is intended to identify bottlenecks and high maintenance areas along the route). Routes are classified by obtaining all pertinent information concerning trafficability and applying it to the route classification formula. DA Forms 1248, 1249, 1250, 1251, and 1252 are designed to help organize reconnaissance data. These forms are covered in greater detail later in this chapter. The route-classification formula is derived from the information gathered during the route reconnaissance. The formula is recorded on the route-classification overlay (see Figure 3-1) and consists of the following:

1. Route width, in meters
2. Route type (based on ability to withstand weather)
3. Lowest military load classification (MLC)
4. Lowest overhead clearance, in meters
5. Obstructions to traffic flow (OB), if applicable
6. Special conditions, such as snow blockage (T) or flooding (W)

Example:

5.5/	Y/	30/	4.6	(OB)	(T or W)
1	2	3	4	5	6

Route Width

The route width is the narrowest width of traveled way on a route (see Figure 3-2). This narrow width may be the width of a bridge, a tunnel, a road, an underpass, or other constriction that limits the traveled-way width. The number of lanes is determined by the traveled-way width. The lane width normally required for wheeled vehicles is 3.5 meters; for tracked vehicles it is 4.0 meters.

Figure 3-2. Route Widths

According to the number of lanes, a road or route can be classified as follows:

Limited access -- Permits passage of isolated vehicles of appropriate width in one direction only;
Single Lane -- Permits use in only one direction at any one time. Passing or movement in the opposite direction is impossible;
Single Flow -- Permits the passage of a column of vehicles and allows isolated vehicles to pass or travel in the opposite direction at predetermined points. It is preferable that such a route be at least 1.5 lanes wide;
Double Flow -- Permits two columns of vehicles to proceed simultaneously. Such a route must be at least two lanes wide.

Route Type

The route type is determined by its ability to withstand weather. It is determined by the worst section of road on the entire route and is categorized as follows:

Type X -- An all-weather route that, with reasonable maintenance, is passable throughout the year to a volume of traffic never appreciably less than its maximum capacity. This route type is normally formed of roads having waterproof surfaces and being only slightly affected by rain, frost, thaw, or heat. This route type is never closed because of weather effects other than snow or flood blockage.
Type Y -- A limited, all-weather route that, with reasonable maintenance, is passable throughout the year but at times having a volume of traffic considerably less than maximum capacity. This route type is normally formed of roads that do not have waterproof surfaces and are considerably affected by rain, frost, thaw, or heat. This route type is closed for short periods (up to one day at a time) by adverse weather conditions during which heavy use of the road would probably lead to complete collapse.
Type Z -- A fair weather route passable only in times of clear weather with little or no rain or snow. The route type is so seriously affected by adverse weather conditions that it may remain closed for long periods. Improvement of such a route can only be achieved by construction or realignment.

Military Load Classification (MLC)

A route's MLC is a class number representing the safe load-carrying capacity and indicating the maximum vehicle class that can operate on the route under normal conditions. Usually, the lowest bridge MLC (regardless of the vehicle type or conditions of traffic flow) determines the route's MLC. If there is not a bridge on the route, the worst section of road will determine the route's overall classification.

In cases where vehicles have a higher MLC than the route, an alternative route may be sought or an additional reconnaissance of the roads within the route may be necessary to determine whether a change in traffic flow (such as single-flow crossing of a weak point) will permit heavier vehicles on the route. When possible, locate some heavy traffic roads within the route network, as well as average traffic roads. This helps staff planners manage heavy traffic loads and minimize choke points or bottlenecks along the route.

The entire network's class is determined by the minimum load classification of a road or bridge within the network. These are the broad categories:

Class 50 -- average traffic route
Class 80 -- heavy traffic route
Class 120 -- very heavy traffic route

Overhead Clearance

The lowest overhead clearance is the vertical distance between the road surface and any overhead obstacle (e.g., power lines, tunnels, overpasses, etc.) that denies the use of the road to some vehicles. Use the infinity symbol (∞) for unlimited clearance in the route classification formula. Points along the route where the minimum overhead clearance is less than 4.3 meters are considered to be obstructions.

Route Obstructions

Route obstructions restrict the type, amount, or speed of traffic flow. They are indicated in the route classification formula by the abbreviation (OB). If an obstruction is encountered, its exact nature must be depicted on the route classification overlay. Obstructions include:

- Overhead obstructions such as tunnels, overhead wires, etc. and overhanging buildings with a clearance of less than 4.3 meters;
- Reductions in traveled way widths that are below the standard minimums prescribed for the type of traffic flow (see Table 3-1). This includes reductions caused by bridges, tunnels, craters, lanes through minefields, rubble, etc.;
- Slopes (gradients) of seven percent or greater;

Curves with a radius of 25 meters and less. Curves with a radius of 25.1 to 45 meters are not considered to be an obstruction; however, they must be recorded on the route reconnaissance overlay;

Ferries;

Fords.

Table 3-1. Traffic Flow Capabilities Based on Route Width

	Limited Access	Single Lane	Single Flow	Double Flow
Wheeled	At least 3.5m	3.5m to 5.5m	5.5m to 7.3m	Over 7.3m
Tracked and combination vehicles	At least 4.0m	4.0m to 6.0m	6.0m to 8.0m	Over 8.0m

<u>Snow Blockage and Flooding</u>

In cases where snow blockage is serious and is blocking traffic on a regular and recurrent basis, the symbol following the route classification formula is (T). In cases where flooding is serious and is blocking traffic on a regular and recurrent basis, the symbol following the route classification formula is (W).

Examples of the Route Classification Formula

The following are examples depicting the use of the route classification formula:

6.1m/Z/40/¥--A fair weather route (Z) with a minimum traveled way of 6.1 meters, and an MLC of 40. Overhead clearance is unlimited (∞) and there are no obstructions to traffic flow.

This route, based on its minimum traveled way width, accommodates both wheeled and tracked, single flow traffic without obstruction.

6.1m/Z/40/¥/(OB)--A fair weather route (Z) similar to the previous example, except there is an obstruction. This obstruction could consist of overhead clearances of less than 4.3 meters, grades of 7 percent or greater, curves with a radius of 25 meters and less, or fords and ferries.

Degrees of Slope	Mils of Slope	Percent of Slope

A traveled way of 6.1 meters limits this route to one-way traffic without a width obstruction. If the route is used for double-flow traffic, then 6.1 meters of traveled way is considered an obstruction.

7m/Y/50/4.6(OB)--A limited, all-weather route (Y) with a minimum traveled way of 7 meters, an MLC of 50, an overhead clearance of 4.6 meters, and an obstruction. This route width is not suitable for double-flow traffic (wheeled or tracked). This width constriction is indicated as OB in the route classification formula if the route is used for double-flow traffic.

10.5m/X/120/¥(OB)(W)--An all-weather route (X) with a minimum traveled way width of 10.5 meters, which is suitable for two-way traffic of both wheeled and tracked vehicles; an MLC of 120; unlimited overhead clearance; an obstruction; and regular, recurrent flooding.

Curve Calculations

The speed at which vehicles move along a route is affected by sharp curves. Curves with a radius of 25 meters and less are obstructions to traffic and are indicated by the abbreviation “OB” in the route classification formula and identified on DA Form 1248. Curves with a radius between 25.1 meters and 45 meters are recorded on the overlay but are not considered obstructions.

MEASURING METHODS

There are several ways to measure curves: the tape-measure, triangulation, and formula methods.

Tape-Measure Method

A quick way to estimate the radius of a sharp curve is by using a tape measure to find the radius (see Figure 3-3). Imagine the outer edge of the curve as the outer edge of a circle. Find (estimate) the center of the imaginary circle; then measure the radius using a tape measure. Start from the center of the circle and measure to the outer edge of the curve. The length of the tape measure from the center of the imaginary circle to its outer edge is the curve’s radius. This method is practical for curves located on relatively flat ground and having a radius up to 15 meters.

Figure 3-3. Tape-measure Method

Triangulation Method

You can determine a curve's approximate radius by "laying out" right triangles (3:4:5 proportion) at the point of curvature (PC) and point of tangency (PT) locations (see figure 3-4). The intersection (o), formed by extending the legs of each triangle, represents the center of the circle. The distance (r) from point 'o' to either point PC or PT represents the curve's radius. This method is useful when terrain prevents estimating a center point or the radius is significantly greater than the available tape measure.

Figure 3-4. Triangulation Method

Formula Method

Another method of determining the curve's radius (see Figure 3-5) is based on the formula (all measurements are in meters)-

$$R=(C^2/8M)+(M/2)$$

where-

R=radius of curve
C=distance from the centerline of the road to the centerline of the road at the outer extremities of the curve
M=perpendicular distance from the center of the tape to the centerline of the road

Note: When conditions warrant, set M at two meters from the centerline, then measure C two meters from the centerline. Use this method when there is a time limitation or because natural or man-made restrictions prevent proper measurements.

Figure 3-5. Formula Method

Example: If C is 15 meters and M is fixed at two meters, the formula becomes-

$$R=(15^2/16)+2/2$$

The result of this calculation would be an obstruction to traffic flow, and “OB” would be placed in the route-classification formula.

CURVE SYMBOL

Sharp curves with a radius of 45 meters or less are symbolically represented on maps or overlays by a triangle that points to the curve’s exact map location. In addition, the measured value (in meters) for the radius of curvature is written outside the triangle (see figure 3-6). All curves with a radius of 45 meters are reportable and need to be noted on DA Form 1248.

Figure 3-6. Curve Symbol

SERIES OF SHARP CURVES

A series of sharp curves is represented by two triangles, one drawn inside the other. The outer triangle points to the location of the first curve. The number of curves and the radius of curvature for the sharpest curve of the series are written to the outside of the triangle (see figure 3-6).

SLOPE ESTIMATION

The rise and fall of the ground is known as the slope or gradient (grade). Slopes of 7 percent or greater affect the movement speed along a route and are considered an obstruction. The percent of slope is used to describe the effect that inclines have on movement rates. It is the ratio of the change in elevation (the vertical distance to the horizontal ground distance) multiplied by 100 (see figure 3-7). It is important to express the vertical distance and the horizontal in the same unit of measure. Report all slopes greater than 5 percent on the route classification overlay.

Figure 3-7. Percent of Slope Formula

PERCENT OF SLOPE

The following methods are used for determining the percent of slope:

Clinometer Method

A clinometer is an instrument that directly measures percent of slope. It can be found in the SL-3 of the engineer Armored Combat Earthmover (ACE). Many privately owned compasses brought to the field by Marines are capable of measuring vertical angles and can be used to measure percent of slope or used for the angles of slope method, below. Follow the instructions included with the instrument.

Map Method

Use a large-scale map (such as 1:50,000) to estimate the percent of slope quickly. After identifying the slope on the map, find the difference in elevations between the top and bottom of the slope by reading the elevation contours or spot elevation. Then measure and convert the horizontal distance (usually road distance) to the same unit of measurement as the elevation difference. Substitute the vertical and horizontal distances in the percent-of-slope formula and compute the percent of slope (see figure 3-8).

Figure 3-8. Map Method to Determine Percent of Slope

Pace Method

The pace method is a quick way to estimate percent of slope. To use this method it is important to know the height and pace length of each Marine in the reconnaissance team before using this method. As a rule of thumb, the eye level of the average Marine is 1.75 meters above the ground. The pace of the average is 0.75 meters. Marines familiar with their pace count over 100 meters can determine their pace length by dividing 100 meters by their pace count.

Perform the following procedures for the pace method:

7. Stand at the bottom of the slope with head and eyes level;
8. Sight a spot on the slope. This spot should be easily identifiable. If it is not, another member of the team should go forward to mark the location;

9. Walk forward and stand on the marked spot. Record the number of paces. Repeat this procedure until you reach the top of the slope (estimate fractions of an eye level);
10. Compute the vertical distance by multiplying the number of sightings by the eye-level height;
11. Compute the horizontal distance by totaling the number of paces and converting them to meters by multiplying the pace length;
12. Calculate the percent of slope by substituting the values into the percent of slope formula (see figure 3-9). This method considers horizontal ground distance and incline distance as equal, you can obtain reasonable accuracy for slopes less than 30 percent. Using the pace method requires practice to achieve acceptable accuracy. A line level and string can be used to train Marines in the pace method.

Figure 3-9. Pace Method to Determine Percent of Slope

Angle of Slope Method

The angle of slope method is a quick way to estimate the percent of slope. The angle of slope is first measured by using an elevation quadrant, an aiming circle, an M2 compass, or binoculars with a standard reticule. If the instrument used to take the angle of measurement is mounted above ground level, the height difference must be compensated for by sighting above the slope a corresponding, equal distance (the corresponding distance is the distance the instrument is above the ground-see figure 3-10). You must conduct the angle of measurement at the base of the slope. Once you obtain the angle of measurement, refer to Table 3-2 and look in the column corresponding to the measured angle of slope. You can read the percent of slope directly from the table.

Table 3-2. Conversion of Degrees and Mils to Angle of Slope

Figure 3-10. Angle of Slope Method to Determine Percent of Slope

SLOPE SYMBOL

Most vehicles negotiating slopes of 7 percent or greater for a significant distance will be slowed. Such slope characteristics must be accurately reported. The symbols illustrated in figure 3-11 are used to represent various slopes.

Figure 3-11. Percent of Slope Symbols

DESCRIPTION OF SLOPE SYMBOLS

A single arrow along the trace of a route pointing in the uphill direction indicates a grade of at least 5 but less than 7 percent. Two arrowheads represent a grade of at least 7 but less than 10 percent. Three arrowheads represent a grade of at least 10 but less than 14 percent. Four arrowheads represent a grade of 14 percent or more. a symbol is not required for slopes less than 5 percent.

The percent of slope is written to the right of the arrow. When the amp scale permits, the length of the arrow shaft will be drawn to map scale to represent the approximate length of the grade.

Slopes of 7 percent or greater are obstructions to traffic flow and are indicated by the abbreviation "OB" in the route classification formula.

CONSTRICTIONS

Reductions in traveled way widths (constrictions) include narrow streets in built-up areas, drainage ditches, embankments, and battle damage. These constrictions may limit vehicles movement; therefore, the physical dimensions of the vehicles that will be using the route must be known and considered when conducting the route classification.

Constrictions in the traveled way width below minimum requirements are depicted on maps and overlays by two opposing shaded triangles. The width of the usable traveled way (in meters) is written next to the left triangle (see figure 3-12). Constrictions of traveled way widths below the minimum standard for the type and flow of traffic are obstructions and are indicated by the symbol "OB" in the route classification formula.

Figure 3-12. Route Constriction Symbol

3003. ROADS

Engineers perform road reconnaissance to collect technical data to determine the traffic capabilities of a road within a route. In general, a road consists of a road surface, base course, and subgrade (see figure 3-13).

Figure 3-13. Parts of a Road

BASE COURSE AND SUBGRADE

The base course and subgrade are the intermediate fill. They are usually composed of gravel or crushed rock. Soils may form the subgrade. See Tables 3-3A, 3-3B, and 3-4.

ROAD CAPACITY COMPUTATIONS

The charts that follow will help give you an accurate estimation of the load-bearing capacity of a road with flexible pavement. Tables 3-3A & B, 3-4, 3-5, and figure 3-14 will help determine the road's load bearing capacity. The load bearing capacity of a road for wheeled vehicles is made by measuring the thickness of the surface and base course and determining the type of subgrade material.

Table 3-3A. Soil Characteristics of Roads and Airfields

Major	Divisions	Letters		Names	Field CBR
Coarse-grained soils	Gravel and gravelly soils	GW		Well-graded gravels or gravel-sand mixtures, little or no fines	60-80
		GP		Poorly graded gravels or gravel-sand mixtures, little or no fines	25-60
		GM	d[1]	Silty gravels, gravel-sand-silt mixtures	40-80
			u[2]		20-40
		GC		Clayey gravels, grave-sand-clay mixtures	20-40
	Sand and sandy soils	SW		Well-graded sands or gravelly sands, little or no fines	20-40
		SP		Poorly graded sands or gravelly sands, little or no	10-25

				fines	
		SM	d[1]	Silty sands, sand-silt mixtures	20-40
			u[2]		10-20
		SC		Clayey sands, sand-clay mixtures	10-20
Fine-grained soils	Silts and clays (liquid limits >50)	ML		Inorganic silts and very fine sands, rock flour, silty, or clayey fine sands, or clayey silts with slight plasticity	5-15
		CL		Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	5-15
		OL		Organic silts and organic silt-clays of low plasticity	4-8
	Silts and clays (liquid limits <50)	MH		Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	4-8
		CH		Inorganic clays of high plasticity, fat clays	3-5
		OH		Organic clays of medium to high plasticity, organic silts	3-5
Highly organic soils		Pt		Peat and other highly organic soils	None
				[1] Indicates liquid limits is 28 or less, and plasticity index is 6 or less. [2] Indicates liquid limit is 28 or greater.	

Table 3-3B. Soil Characteristics of Roads and Airfields

Letters		Value as Foundation When Not subject to Frost Action [3]	Value as Base Directly Under Bituminous Pavement	Potential Frost Action [4]	Compressibility and Expansion	Drainage Characteristics
GW		Excellent	Good	None to very slight	Almost none	Excellent
GP		Good to excellent	Poor to fair	None to very slight	Almost none	Excellent
GM	d[1]	Good to excellent	Fair to good	Slight to medium	Very slight	Fair to poor
	u[2]	Good	Poor	Slight to medium	Slight	Poor to practically impervious
GC		Good	Poor	Slight to medium	Slight	Poor to practically impervious
SW		Good	Poor	None to very slight	Almost none	Excellent
SP		Fair to good	Poor to not suitable	None to very slight	Almost none	Excellent
SM	d[1]	Good	Poor	Slight to high	Very slight	Fair to poor
	u[2]	Fair to good	Not suitable	Slight to high	Slight to medium	Poor to practically impervious
SC		Fair to good	Not suitable	Slight to high	Slight to medium	Poor to practically impervious
ML		Fair to poor	Not suitable	Medium to	Slight to	Fair to poor
CL		Fa				
OL		Po				
MH		Po				
CH		Po po				
OH		Po po				
Pt		N				

[3] Values are for su
[4] Indicates whethe

Table 3-4. Principal Soil Types

Name	Description
Gravel	A mass of detached rock particles, generally water-worn, which passes a 3 inch sieve and is retained on a No. 4 sieve (0.187 inches).
Sand	Granular material composed of rock particles which pass a No. 4 sieve (0.187 inches) and are retained on a No. 200 sieve (0.0029 inches). It is difficult to distinguish sand from silt when the particles are uniformly small. Dried sand, however, differs from silt in that it has no cohesion and feels grittier.
Silt	A fine, granular material composed of particles which pass the No. 200 sieve (0.0029 inches). It lacks plasticity and has little dry strength. To identify, prepare a pat of wet soil and shake it horizontally in the palm of the hand. With typical inorganic silt, the shaking action causes water to come to the surface of the sample, making it appear glossy and soft. Repeat tests with varying moisture contents. Squeezing the sample between the fingers causes the water to disappear from the surface and the sample and the sample quickly stiffens and finally cracks or crumbles. allow sample to dry, test its cohesion, and feel by crumbling with the fingers. Typical silt shows little or no dry strength and feels only slightly gritty in contrast to the rough grittiness of fine sand.
Clay	Extremely fine grained material composed of particles which pass the No. 200 sieve (0.0029 inches). To identify, work a sample with the fingers, adding water when stiffness requires. Moist sample is plastic enough to be kneaded like dough. Test further by rolling ball of kneaded soil between palm of hand and flat surface. Clay can be rolled to a slender thread, about ¼ inch in diameter, without Crumbling; silt crumbles, without forming a thread. Measure hardness of dry clay by finger pressure required to break a sample. It requires much greater force to break dry clay than dry silt. Clay feels smooth in contrast to the slight grittiness of silt.
Organic	Soil composed of decayed or decaying vegetation, sometimes mixed with fine grained mineral sediments such as peat or muskeg. It is identified by coarse and fibrous appearance and odor. Odor may be intensified by heating. Plastic soils containing organic material can be rolled into soft, spongy threads.

Table 3-5. Maximum Axle and Wheel Loads for Wheeled Vehicles

Hypothetical Vehicle Class Number	Maximum Single-axle Load (in tons)	Maximum Single-Wheel Load (in pounds x 1000)
4	2.5	2.5

8	5.5	5.5
12	8	8
16	10	10
20	11	11
24	12	12
30	13.5	13.5
40	17	17
50	20	20
60	23	20
70	25.5	20
80	28	20
90	30	20
100	32	20
120	36	20
150	42	21

Figure 3-14. Load Bearing Capacity of Roads With a Flexible Surface

ROAD CLASSIFICATION FORMULA

The road classification formula is a systematic way of describing the worst section of a road. Do not confuse it with the route classification formula. Recorded information from the road classification formula is included in the route classification formula. The following paragraphs describe each portion of the formula shown below:

Bgs	4/5	r	(8 km)	(OB)	(T)
(1)	(2)	(3)	(4)	(5)	(6)

Limiting characteristics. Prefix the formula with "A" if there are no limiting characteristics and "B" if there are one or more limiting characteristics. Represent an unknown or undetermined characteristic by a question mark, together with the feature to which it refers. In the example above, the letter "g" indicates steep gradients and the letter "s" indicates a rough surface (see Table 3-6).

Minimum traveled way width. Express this width in meters followed by a slash and the combined width of the traveled way and the shoulders. In the example above, the minimum traveled way is 4 meters and the combined width is 5 meters.

Road surface material. Express this with a letter symbol. The formula above describes the surface material as "r", meaning water bound macadam. Use the symbols listed in Table 3-7; they are further related to the X, Y, and Z route types of the route classification described earlier in route-recon procedures.

Road length. Express the road length in kilometers and place in parentheses.

Obstructions. Indicate any obstructions along a road by placing the symbol "OB" after the road length, as shown in the example above. Details of the obstructions are not shown in the formula; they are reported separately by appropriate symbols on accompanying maps, overlays, or on DA Form 1248. Report the following obstructions:

Overhead obstructions (less than 4.3 meters over the route);

Constrictions in traveled way widths less than 6 meters for single-flow traffic or less than 8 meters for double-flow traffic (tracked or combination vehicles, see Table 3-1);

Slopes of 7 percent or greater;

Curves with a radius of less than 25 meters (report curves of 25.1 meters to 45 meters).

Blockage. If blockage is regular, recurrent, and serious, then the effects of snow blockage and flooding are indicated in the road classification formula. The symbol for snow blockage is "T" and the symbol for frequent flooding is "W".

Table 3-6. Symbols for Limiting Characteristics

Limiting Characteristics	Criteria	Symb
Sharp curves	Sharp curves with radius of 25 meters and less (82 ft); are also reported as obstructions	c
Steep gradients	Steep gradients, 7 percent or steeper; such gradients are also reported as obstructions	g
Poor drainage	Inadequate ditches, crown or camber, or culverts; culverts and ditches blocked or other wise in poor condition	d
Weak foundation	Unstable, loose, or easily displaced material	f
Rough surface	Bumpy, rutted, or potholed to an extent likely to reduce convoy speeds	s
Excessive camber or superelevation	Falling away so sharply as to cause heavy vehicles to skid or drag toward	j

Table 3-7. Symbols for Type of Surface Materials

Symbol	Material	Route Type
k	Concrete	Type X; generally heavy duty
kb	Bituminous (asphaltic) concrete (bituminous plant mix)	Type X; generally heavy duty
p	Paving brick or stone	Type X or Y; generally heavy duty
pb	Bituminous surface on paving brick or stone	Type X or Y; generally heavy duty
rb	Bitumen-penetrated macadam, water-bound macadam with superficila asphalt or tar cover	Type X or Y; generally medium duty
r	Water-bound macadam, crushed rock or coral or stabilized gravel	Type X or Y; generally light duty
l	Gravel or lightly metaled surface	Type X or Y; generally light duty
nb	Bituminous surface treatment on natural earth, stabilized soil, sand-clay, or other selected material	Type X or Y; generally light duty
b	Used when type of bituminous construction cannot be determined	Type X or Y; generally light duty
n	Natural earth stabilized soil, sand-clay, shell, cinders, disin-tegrated granite, or other selected material	Type X or Y; generally light duty
v	Various other types not mentioned above	Classify X, Y, Z depending on the type of material used (indicate length when this symbol is used)

The following are examples of road classification formula:

A 5.0/6.2k -- road with no limiting characteristics or obstructions, a minimum traveled way of 5.0 meters, a combined width of traveled way and shoulders of 6.2 meters, and a concrete surface;

B g s 4/5 1 (OB) -- road with limiting characteristics of steep gradients and a rough surface, a minimum traveled way of 4 meters, a combined width of 5 meters, gravel or lightly metaled surfaces, and obstructions;

B c(f?) 3.2/4.8 p (4.3km) (OB) (T) -- road with limiting characteristics of sharp curves and unknown foundation, a minimum traveled way of 3.2 meters, a combined width of 4.8 meters, paving brick or stone surface, obstructions and that is 4.3 kilometers long, subject to snow blockage.

Where rock slides are a hazard or poor drainage is a problem, include information on a written enclosure or legend. DA Form 1248 is primarily self-explanatory. Ensure that a new classification formula is entered along the road each time the road conditions significantly change.

3004. UNDERPASSES

An underpass is depicted on a map or overlay by a symbol that shows the structure's ceiling. It is drawn over the route at the map location. The width (in meters) is written to the left of the underpass symbol, and the overhead clearance (in meters) is written to the right of the underpass symbol (see figure 3-15).

If sidewalks permit passage of wider vehicles, the sidewalks are symbolically represented. This information should be noted on DA Form 1250. The traveled way width is recorded first, followed by a slash, then the structure's total width, including sidewalks. Items such as arched ceilings or irregularities in ceilings that result in a decrease in overhead clearance must be noted. In such cases, an extension of width may not mean that the structure will accommodate wider vehicles. Both minimum and maximum overhead clearances, if different, will be recorded. The minimum will be recorded first, followed by a slash, then the maximum overhead clearance.

Figure 3-15. Underpass Symbols

3005. TUNNELS

A tunnel is an artificially covered (such as a covered bridge or a snowshed) or underground section of road along a route. A tunnel reconnaissance determines essential information, such as the serial number, location, type, length, width (including sidewalks), bypasses, alignment, gradient, and cross section. A tunnel consists of a bore, a tunnel liner, and a portal. Common shapes of tunnel bores (see figure 3-16) are semicircular, elliptical, horseshoe, and square with an arched ceiling.

Figure 3-16. Types of Tunnel Bores

TUNNEL SYMBOL

Basic tunnel information is recorded on maps or overlays using symbols (see figure 3-17). The location of the tunnel entrance is shown on a map or overlay by an arrow from the symbol to the location of the entrance. For long tunnels (greater than 30.5 meters), both tunnel entrance locations are indicated.

For later reference, a serial number is assigned to each tunnel (check for an existing fixed serial number on the actual tunnel or map sheet; if there is not a serial number, assign a number based on the unit's SOP). Serial numbers are not duplicated on any one map sheet, overlay, or document. The number is recorded inside the symbol. The traveled way width is shown in meters and is placed below the symbol.

If sidewalks permit the emergency passage of wider vehicles, then the sidewalks are symbolically represented and the traveled way width is written first, followed by a slash, then the total width, including the sidewalks. Items such as arched ceilings or irregularities in ceilings that result in a decrease in overhead clearance must be noted. In such cases, an extension of width may not mean that the structure will accommodate wider vehicles. Both minimum and maximum overhead clearances, if different, will be recorded. The minimum will be recorded first, followed by a slash, then the maximum overhead clearance.

Figure 3-17. Tunnel Symbols

OVERHEAD CLEARANCE

Overhead clearance is the shortest distance between the surface of a traveled way and any obstruction vertically above it. The measurement of overhead clearance must be accurate. Obtain the measurements shown in figures 3-18 and 3-19 and record them on DA Form 1250.

Figure 3-18. Overhead Clearance Measurements

Figure 3-19. Dimensions Required for Tunnels

A stream crossing site is a location at a body of water where vehicles can cross and not touch the bottom. Identify and report locations that permit smooth traffic flow and reduce route obstructions as much as possible. When conducting a reconnaissance of a stream crossing area record the stream's depth, width, approaches, velocities, and natural and man-made obstacles (see figure 3-20).

Figure 3-20. Dimensions Required for Streams

MEASUREMENTS

Stream depth is usually measured using field expedient devices, such as poles or weighted ropes. Measure the depth every 3 meters along the planned stream crossing route. Recheck depths and currents frequently during inclement weather. As a result of sudden, heavy rainfall, a sluggish stream or river may become a torrent very quickly, particularly in tropical and arid regions. Monitor weather reports of the surrounding area. Storms occurring miles away can cause flash flooding. Always consider the importance of upstream dams and locks that may cause elevated levels or flooding when opened or destroyed. The actual depth you measure is recorded as normal depth when there is little time to reconnaissance.

PREEXISTING DATA

In developed areas of the world, special water navigation maps containing water-body data are available through government agencies. The G2/S2 can obtain copies of such maps. However, always check the actual site when possible.

STREAM WIDTH

Determine the stream width by using the compass method, a GPS, or by taking a direct measurement.

Compass Method

First Method: Determine stream width by using a compass to take an azimuth from a point on the near shore and close to the water's edge to a point on the opposite shore and close to the water's edge (see figure 3-21). On the near shore, establish another point that is on a line and at a right angle to the first azimuth selected. Taken an azimuth to the same point on the far shore at + or - 45 degrees (800 mils) from the first azimuth. Measure the distance between the two points on the near shore. This distance is equal to the distance across the stream.

Figure 3-21. Measuring Stream Width-First Method

Second Method (requires using trigonometric relationships): Use a compass to measure the angle between two points that are a known distance apart on the near shore and a third point directly across the river from one of these points (see figure 3-22). Using the formula in Figure 3-22 and the tangent table (see Table 3-8), compute the distance across the stream.

Figure 3-22. Measuring Stream Width-Second Method

Global Positioning System

Calculate the distance using two known grid points taken from GPS. Requires crossing the water to a point directly across from the first point and taking the second GPS reading.

Direct Measurement

Measure short gaps with a tape measure or a rope that is marked and accurately measured. Requires crossing the water to a point directly across from the first point.

CURRENT VELOCITIES

The velocity of its current varies in different parts of the stream. Velocity is usually slower near the shore and faster in the main channel. Perform the following procedure to determine stream velocity:

13. Measure a distance in meters along a river bank;
14. Throw a light, floating object (not affected by the wind) into the stream;
15. Record the time of travel it takes for the object to travel the measured distance.

Repeat the procedure at least three times. Use the average time of the tests in the following formula (see figure 3-23) to determine the stream's velocity:

Stream velocity (in meters per second)=measured distance (in meters) divided by average time (in seconds)

Table 3-8. Tangent Table

Degree	Tangent
0	0
1	0.02
2	0.03
3	0.05
4	0.07
5	0.09
6	0.11
7	0.12
8	0.14
9	0.16
10	0.18
11	0.19
12	0.21
13	0.23
14	0.25
15	0.27
16	0.29
17	0.31
18	0.32
19	0.34
20	0.36
21	0.38
22	0.4
23	0.42
24	0.45
25	0.47
26	0.49
27	0.51
28	0.53
29	0.55
30	0.58
31	0.6
32	0.62
33	0.65
34	0.67
35	0.7
36	0.73
37	0.75
38	0.78
39	0.81
40	0.84
41	0.87
42	0.9
43	0.93
44	0.97
45	1

Figure 3-23. Finding Stream Velocity

STREAM APPROACHES

Gently sloping stream approaches are desirable for fording. Slope is expressed in percent. Ensure that the slope-climbing capability is considered for the vehicles that are expected to ford the stream. This information is found on the vehicle's data plate, dash plate, or in the vehicle's technical manual (TM). When considering slope-climbing capability, consider the degrading effects of weather, the condition of the vehicle's tires or tracks, and the condition of the ground surface of both sides of the stream. When bank improvements are necessary, include the amount and type of work on the DA Form 1711-R.

Consider and avoid the following obstacles during stream crossings:

- High, vertical banks;
- Mines and boobytraps that are located at the entrance and exit or at likely approaches, submerged, or attached to poles and floating logs;
- Debris and floating objects, such as logs, brush, poles, or floating logs with wire attached (may foul propellers, tracks, and suspension systems);
- Ice crusts.

3007. FORDS

A ford is a location in a water barrier where the current, bottom, and approaches allow personnel, vehicles, and other equipment to cross and remain in contact with the bottom during crossing. Fords are obstructions to traffic flow and are shown by the abbreviation "OB" in the route classification formula (detailed information is recorded on DA Form 1251).

During high water periods, low water bridges are easily confused with paved fords because both are completely submerged. It is important to know the difference between this type of bridge and a paved ford because of corresponding military load limitations.

Fords are classified according to their crossing potential (or trafficability) for pedestrians or vehicles. Fordable depths for vehicular traffic can be increased by suitable waterproofing and adding deep water fording kits. It is important for the engineers performing the reconnaissance to know what the fording capabilities of the equipment that will use the ford. Fording capabilities can range from 30 inches to over seven feet, depending on the equipment and if fording kits are installed. Check TMs for fording specifics on capabilities.

Record the composition of approaches. Not improvements, if any, and give consideration to potential improvements. The composition and slope of the approaches to a ford should be carefully noted to determine the trafficability after fording vehicles saturate the surface material of the approaches.

Record the current velocity and the presence of debris to determine their effect, if any, on the ford's condition and passability. Use the same method described earlier.

The ford's stream bottom composition largely determines its trafficability. It is important to determine whether the bottom is composed of sand, gravel, silt, clay, or rock and in what proportions. record whether the ford's natural bottom has been improved to increase the load bearing capacity or to reduce the water depth. improved fords may have gravel, macadam, or concrete surfacing; layers of sandbags; metal screening or matting; or timber (corduroy) planking. Note if there is material nearby to use for improving the ford. Record limited ford information (such as the following) on maps or overlays using a symbol as shown in figure 3-24.

Figure 3-24. Ford Symbols

The ford's geographical location is shown by an arrow from the symbol to the ford location on a map or overlay. The symbol is drawn on either side of the stream;

A serial number is assigned to each ford for reference (if there is a preassigned serial taken from a map or data plaque, use it). Follow the unit's SOP in assigning serial numbers if none are available. The numbers must not be duplicated within any one map sheet, overlay, or document;

The type of ford is determined by bottom conditions, width, and water depth. Use the letters "V" for vehicular or "P" for pedestrian to show the ford type. Approaches are not considered in determining the ford type;

The stream's normal velocity is expressed in meters per second. Seasonal limiting factors follow the stream velocity notation and are shown by the letters "X" or "Y":

X=No seasonal limitations except for sudden flooding of limited duration (such as flash floods).

Y=Serious, regular, or recurrent flooding or snow blockage. **If the "Y" symbol is used the route type in the route classification formula automatically becomes type "Z".**

The length of the ford, expressed in meters, is the distance from the near to far shores. The width of the ford is the traveled way width of the ford's bottom.

The nature of the bottom is indicated by the most appropriate letter symbol:

M=Mud
C=Clay
S=Sand
G=Gravel
R=Rock
P=Artifical paving

The normal depth is the depth of the water at the deepest point, expressed in meters.

The last piece of information is describe based on the conditions of the banks. Determining left and right banks is done by facing down stream. Imagine standing in the middle of the stream and looking downstream, the direction of the current. Your left arm indicates the left bank and your right arm the right bank. When drawing this information on a map or overlay ensure you know which direction is downstream on the map or overlay. A difficult approach is shown by irregular lines placed on the corresponding side of the basic symbol.

All elements of the ford symbol are separated by slashes. If you do not know or cannot determine any of the ford characteristics, substitute a question mark for the required information in the symbol. Record detailed ford information on DA Form 1251.

3008. DEEP WATER

In deep waters, generally streams where a person cannot keep their head above water and maintain firm contact with the stream bottom, divers may have to determine bottom conditions. Person trained and equipped for underwater reconnaissance should work with the engineers performing the route reconnaissance in selecting deep-water fording sites. When divers cannot easily span the distance between banks, boats or water craft be required to support the divers.

To assist underwater reconnaissance divers in maintaining direction, weighted lines (traverse lines) may be placed across the bottom. Buoys or other floating devices are attached to the traverse line to help indicated the survey area. If the current is too strong (generally 1.3 meters per second or greater) it may be difficult for the divers to remain in position along the traverse line to conduct the survey. A second, parallel line, up stream from the traverse line can be placed to allow divers to maintain themselves over the ford site traverse line.

Bottom conditions are easily determined during periods of good visibility and when the water is clear. Under blackout conditions or when the water is murky, the reconnaissance is much slower. Plan mission time tables accordingly. If the tactical conditions permit, divers may use underwater lanterns.

Environmental conditions (such as depth, bottom type, tides and currents, visibility, and temperature) have an effect on divers, diving techniques, and equipment. The length of time divers can remain underwater depends on water depth, time at depth, and equipment used. When conducting a reconnaissance in a current, swimmers expend more energy, tire more easily, and use air more quickly. In water temperatures between 73 and 85 degrees F, divers can work comfortably without wet suits, but will chill in one to two hours if not exercising. In water temperatures above 85 degrees F, the divers may overheat. The maximum water temperature that can be endured, even at rest, is 96 degrees F. At temperatures below 73 degrees F, unprotected divers will be affected by excessive heat loss within a short period of time. In cold water, the sense of touch and the ability to work with the hands are affected. Air tanks vary in size and govern how long divers can operate. Extra tanks should be available for underwater reconnaissance teams and facilities to recharge them should be located close enough to the divers to respond to requirements.

3009. FERRIES

Ferries are considered obstructions to traffic flow and are indicated by the letters "OB" in the route classification formula. Ferryboat construction varies and ranges from expedient rafts to ocean-going vessels. Ferries differ in physical appearance and capacity depending upon the water's depth. width, and current and the characteristics of the traffic to be moved. Ferries may be propelled by oars, cable and pulleys, poles, the stream current, or steam, gasoline or diesel engines.

NONMILITARY FERRIES AND FERRY SITES

Usually, the capacity of a nonmilitary ferryboat is expressed in tons and total number of passengers. In addition, it is often assigned an MLC number. Ensure that you record the capacity of each ferry when more than one vessel is used at a site as the ferries may vary in capacity.

Ferry slips or piers are usually provided on each shore to permit loading of passengers, cargo, and vehicles. The slips may range from simple log piers to elaborate terminal buildings. A distinguishing characteristic of a ferry slip is often the floating pier that adjusts, with changes in the water depth, to the height of the ferryboat.

Approach routes to ferry installations have an important bearing on using the ferry. Reconning and recording the conditions of the approaches (including the load-carrying capacity of landing facilities) is very important.

Limiting characteristics of ferry sites that should be considered are:

- Width of the water barrier from bank to bank;
- Distance and time required for the ferryboat to travel across one-way and round trip;
- Depth of the water at each ferry slip;
- Ease in which each landing site can be defended.

Climatic conditions affect ferry operations. Fog and ice substantially reduce the total traffic moving capacity and increase the hazard of the water route. Therefore, you must consider data on tide fluctuations, freezing periods, floods, excessive dry spells, and their effects on ferry operations.

FERRY INFORMATION

Record limited ferry information (such as the following) on maps or overlays by using the symbol shown in figure 3-25 and 3-26:

- The geographic location of the ferry is shown by an arrow from the symbol to the location of the ferry on a map or overlay. The symbol may be drawn on the map or overlay on either side of the stream;
- A serial number is assigned to each ferry, for later reference. Numbers must not be duplicated within any one map sheet, overlay, or document. Some maps will already show a ferry serial number, use this number if available. If you do not find a number, record a number according to the unit's SOP;
- The type of ferry (V for vehicular and P for pedestrian) is shown after the serial number. If the ferry can haul vehicles, it can also haul pedestrians;
- The deck's MLC is placed in the bottom left box of the symbol. Most ferries have this information on their data plate;

The dead weight capacity of the ferry is the MLC plus the actual weight of the ferry, in short tons;

The turnaround time is shown by the number of minutes required to cross the water obstacle, unload, and return.

Figure 3-25. Ferry Symbol

Figure 3-26. Sample of Completed Ferry Symbols

When drawing the approach condition portion of the symbol, ensure the left and right approaches correspond with the current. Left and right banks are determined by looking downstream. Approach conditions are determined in the same manner as for fords. A difficult approach is shown by irregular lines placed on the corresponding side of the basic symbol. A question mark is used for unknown or undetermined information. Detailed ferry reconnaissance information is recorded on DA Form 1252.

3010. MILITARY FERRY AND RAFTING

Engineer reconnaissance will be required to locate and report suitable sites for military rafting or ferrying operations. Military floating bridges are also available for such operations. Desirable site characteristics are:

- Current velocities between 0 and 1.6 meters per second;
- Banks that permit loading without a great deal of preparation;
- Approaches that permit easy access and egress;
- Strong, natural holdfasts (points to secure the raft or ferry);
- Sites with no shoals, sandbars, or snags;
- Sites clear of obstacles immediately downstream;
- Sites clear of mines and boobytraps;
- Sites with enough depth to prevent grounding the raft or ferry during loading and unloading operations or when crossing;
- Suitable raft construction sites (dependent on type of raft);
- Holding areas for vehicles awaiting passage;
- A suitable road network to support crossing traffic.

3011. BRIDGES

A bridge reconnaissance provides commanders with the bridge load carrying capabilities along a certain route or what materials is needed to destroy a bridge. Because of the complexity of analyzing bridges, all bridge reconnaissance should be performed by engineers.

3012. REQUIRED BRIDGE INFORMATION FOR CLASSIFICATION PROCEDURES

This manual reviews the basics of bridge load classification and bridge destruction analysis. The bridge load classification covered in this chapter is adequate for most bridge reconnaissance. It allows vehicle operators to avoid bridge failure by determining what can cross without causing damage. Vehicle operators may cross without restrictions if their vehicle’s load class (including the load) is less than or equal to the bridge’s load class. The vehicle’s load class can be found in the vehicle’s TM.

This chapter covers the most common bridges in existence today and includes sign marking systems, analysis worksheets and other necessary data needed to collect analyze, classify, and mark a bridge. Common bridges in use today include:

- Timber or steel trestle bridge with timber deck;
- Steel stringer bridge with concrete deck;
- Concrete steel stringer bridge;
- Concrete T-beam bridge with asphalt surface;
- Masonry arch bridge.

REQUIRED INFORMATION

To classify a bridge, you must know the information concerning the bridge's basic components, including the following:

- **Approaches (the portions of a route leading to a bridge).** Approaches may be mined or boobytrapped, requiring thorough investigation during a reconnaissance;
- **Substructure (lower part of a bridge).** The substance consists of the abutments and intermediate supports that transfer the bridge's load to the ground. It is important to measure all aspects of an abutment, including its height, width, and length; the abutment wings; and the intermediate supports for bridge demolition missions. It may be more feasible to destroy the intermediate supports or abutments when compared to the rest of the bridge structure;
- **Superstructure (upper part of a bridge).** The superstructure consists of the following components (see figure 3-27):
    - Stringers rest on and span the distance between the intermediate supports or abutments. Stringers are the superstructure's main load-carrying members. They receive the load from the flooring and the vehicles and transfer it to the substructure;
    - The flooring system often consists of both decking and tread. The decking is laid directly over the stringers at right angles to the centerline of the bridge. The tread is laid parallel to the centerline of the bridge and between the curbs;
    - Curbs are placed at both edges of the flooring to guide the vehicles. A vehicle with an axle that is wider than the traveled way width (between the curbs) cannot cross the bridge. Most bridges, however, allow for vehicular overhang beyond the normal traveled area. This allowance is called horizontal clearance above the curbs and is a safety factor. Commanders must perform a risk analysis before attempting such a crossing;
    - Railings along the bridge are built to guide drivers and to protect vehicular and foot traffic;
    - Trusses are used in some bridge superstructures, either above or below the traveled way to increase the load carrying capacity. A truss is a structural element made of several members joined together to form a series of triangles;
    - The number of members in each span is noted where applicable (for example, stringer bridges and concrete T-beam bridges). Exact dimensions of specific bridge members are taken as outlined later in this chapter;
    - The span length is measured from center to center of the supports. The bridge's classification is usually based on the weakest span. If the weakest span is apparent, no other spans need to be measured. If the weakest span is difficult or impossible to locate, all spans must be

classified. Even if several spans look identical, actual measurements should be taken to prevent error;
The traveled way width is measured between the insides faces of the curbs. The horizontal clearance on a truss bridge is measured from a point 1.21 meters above the roadway.

Figure 3-27. Bridge Parts

BRIDGE CONDITION

It is essential to note the bridge’s general condition, paying particular attention to evidence of damage from natural causes (e.g., rot, rust, and deterioration) or combat action. Classification procedures presume that a bridge is in good condition. If the bridge is in poor condition, the class obtained from mathematical computations must be reduced according to the classifier’s judgment.à¬>->`

WIDTH AND HEIGHT RESTRICTIONS

Table 3-9 lists width restrictions for bridges. If a one lane bridge does not meet width requirements and this is a route restriction, annotate it in the route classification formula. For a two lane bridge, downgrade the two way classification to the highest class for which it does qualify (one way class is not affected). Post a limited clearance sign if the overhead clearance is less than 4.3 meters.

Table 3-9. Minimum Roadway Widths

Roadway Width (meters)	**Bridge Classification**	
	One-way	**Two-way**
2.75 to 3.34	12	0
3.35 to 3.99	30	0
4.00 to 4.49	60	0
4.50 to 4.99	100	0
5.00 to 5.40	150	0
5.50 to 7.20	150	30
7.30 to 8.10	150	60
8.20 to 9.70	150	100

Over 9.80	150	150
Minimum overhead clearance for all classes is 4.3 meters.		

3013. BRIDGE RECONNAISSANCE REPORT

A systematic bridge reconnaissance obtains valuable data. Use DA Form 1249 to report information concerning any reconned bridge, as follows:

Column 1. Record the assigned serial number. This number matches the serial number used in the bridge symbol of the route classification overlay;
Column 2. Record the grid coordinates, with the map identifier, of the actual bridge site;
Column 3. Record horizontal clearance information in meters. Horizontal clearance is the clear distance between the inside edges of the bridge structure, measured at a height of 0.3 meters above the surface of the traveled way. Horizontal clearance for a truss bridge is measured 1.21 meters above the traveled way. Any horizontal clearance less than the minimum required for the bridge's roadway width (as shown in Table 4-9) is underlined. Unlimited clearance is indicated by the symbol "∞".
Column 4. Record under-bridge clearance, in meters. It is the clear distance between the underside of each span and the surface of the water. The height above the stream bed and the height above the estimated normal water level (pertaining to the appropriate bridge type) are included in this column for each span;
Column 5. Record the number of spans. Spans are listed in sequence starting from the west. If the bridge is oriented more north to south, start with the northern most span and work south. Place the letter N in column 5 before the span and list in sequence;
Column 6. Record the type of span construction. Refer to diagrams in figure 3-28;
Column 7. Record the type of construction material. Refer to Table 3-10 for this information;
Column 8. Record span length, in meters. This is a center-to-center spacing between bearings. The sum of the span length may not equal the overall length. Spans that are not usable because of damage or destruction are indicated by the pound symbol (#), placed after the dimension of the span length. Spans that are over water are indicated by placing the letter "W" after the dimension of the span length.

Table 3-10. Construction Material

Material of Span Construction	Letter Symbol
Steel or other metal	a
Concrete	k
Reinforced concrete	ak
Prestressed concrete	kk
Stone or brick	p
Wood	h
Other (to be specified by name)	o

Figure 3-28. Typical Bridge Spans

OTHER INFORMATION

When an abbreviated bridge symbol is used or when a reconnaissance mission requires it, columns are added to give the MLC, overall length, roadway width, overhead clearance, and bypass possibilities (specify use easy, use difficult, or use impossible). Indicate whether the bridge is supported or continuous.

BRIDGE SKETCHES

Show as much information as possible when sketching the bridge on the backside of DA Form 1249 (see figure 3-29).

Figure 3-29. Sample Bridge Sketch

3014. BRIDGE CLASSIFICATION PROCEDURES (WORKSHEETS AND TABLES)

The following worksheets, figures, and tables are used to determine the classification to give to a bridge. The data collected from the reconnaissance and the data contained in the tables and figures are utilized in the worksheets' computations. The computations will yield a classification result to assign to a bridge.

The following worksheets cover the six most common bridge construction types likely to be encountered. The six common types are (figures 3-30 to 3-35):

Figure 3-30. Timber or Steel Trestle Bridge With Timber Deck

Figure 3-31. Steel-stringer Bridge With Concrete Deck (Noncomposite Construction)

Figure 3-32. Concrete Steel-stringer Bridge (Composite Construction)

Figure 3-33. Concrete T-beam Bridge With asphalt Wearing Surface.

Figure 3-34. Concrete Slab Bridge With Asphalt Wearing Surface

Figure 3-35. Masonry-arch Bridge

Other necessary tables and graphs required to complete these worksheets can be found in Appendix D, Bridge Classification Factors.

3015. BRIDGE SYMBOL

Bridge information is recorded on a map or overlay by using the full NATO bridge symbol (see figure 3-36). Accurate bridge information is important for planning operations and their support missions. the NATO symbol is intended to convey all necessary information in a concise, standardized method. The bridge symbol contains the following:

- Bridge's serial number;
- Geographical location;
- Bridge's MLC;
- Overall length;
- Overhead clearance;
- Available bypasses.

Figure 3-36. Full NATO Bridge Symbol

A bridge serial number is assigned for future reference and is recorded in the symbol's lower portion (assign a number according to the unit's SOP or the actual serial number taken from the bridge's data plate). For proper identification, do not duplicate serial numbers within any one map sheet, overlay, or document. The unit's G2/S2 can often obtain special maps containing bridge information for developed areas of the world.

The bridge's geographical location is shown by an arrow extending from the symbol to the exact map location. The bridge's MLC number is shown in the symbol's top portion. This number indicates the bridge's carrying capacity; classifications for both single and double flow traffic are included. In those instances where dual classifications for wheeled and tracked vehicles exist, both classifications are shown.

The bridge's overall length is the distance between abutments, measured along the bridge's centerline. This figure is placed to the right of the circle and is expressed in meters.

The minimum lane width is the clear distance between curbs. Place this figure below the symbol and express in meters. Bridges may be an obstruction to traffic flow because the traveled-way width of the overall route may be reduced by the width of the bridge. Use the width requirements for traffic flow found in chapter 4 to determine if a bridge meets the minimum requirements for one or two way traffic flow.

Overhead clearance is the minimum distance between the bridge's surface and any obstruction above it. This figure is shown in meters to the left of the symbol. Underline any overhead clearance less than the minimum required by the bridge class number as found in this chapter. Unlimited overhead clearance is indicated by the symbol "∞". Report any overhead clearance less than 4.3 meters as an obstruction in the route-classification formula. A question mark is used to indicate information that is unknown or undetermined and is included as part of the bridge reconnaissance symbol.

3016. BYPASSES

Bypasses are detours along a route allowing traffic to avoid an obstruction. Bypasses are limited to specific vehicle types, such as those capable of swimming or deep-water fording, are noted on the reconnaissance report. Bypasses are classified as easy, difficult, or impossible. Each type of bypass is represented symbolically on the arrow extending from the tunnel, ford, bridge, or overpass symbol to the map location (see Table 3-11).

Table 3-11. Bypass Symbols

	Bypass easy. Use when the obstacle can be crossed in the immediate vicinity by a US 5-ton truck without work to improve the bypass.
	Bypass difficult. Use when the obstacle can be crossed in the immediate vicinity, but some work to improve the bypass is necessary. (Provide initial estimates of time, personnel, and equipment necessary to prepare the bypass in the reconnaissance report)
	Bypass impossible. Use when the obstacle can be crossed only by repairing the existing obstruction or constructing a detour around the obstacle.

Chapter 4

Route Signs and Symbols

An engineer reconnaissance mission may be tasked with establishing signage during the route reconnaissance or the information gathered will be used by other units to emplace signs as required. This chapter provides guidance for implementing STANAGs 2027 and 2154. These procedures for making and posting military routes are standardized for NATO forces. However, this system may be integrated into other road-sign systems as required by local or other military requirements.

Engineers are responsible for providing the MAGTF or AO commander the information necessary to ensure proper signage for traffic controls that are implemented. Engineer units may be assigned the task of acquiring or making and installing the signs but nonengineer units may also be required to perform this function. Standard signage is used to aid drivers when encountering a bridge. When necessary additional signs may be used to provide all necessary information.

4001. GUIDE SIGNS

There are three general types of standard route signs--hazard, regulatory, and guide. Table 4-1 lists the way each type may be used. The size of these signs is not prescribed; they must be large enough to be easily read under poor lighting conditions. Exceptions to this rule are bridge classification signs for which dimensions are specific. As a guide, signs for civil international road use are usually not less than 16 inches across.

Table 4-1. Typical Hazard, Regulatory, and Guide Signs

	Type		
	Hazard	**Regulatory**	**Guide**
	Advance warning of stop signs and traffic signals	No entry	Detour
	Changes in road width	One way	Detour begins
	Crossroads	Parking restrictions	Detour ends
	Curves	Specific regulations for vehicles	Directions
	Danger or hazard	Speed limit	Distances
	Dangerous corner	Stop	Information to help driver
	Dips	Bridge Classification	Locations
	Junction T		Route number
	Junction Y		
Applications	Level railroad crossing, advance warning		
	Men working		
	Railroad crossing		
	Road construction or repair		
	Road narrows		
	Slippery road		
	Steep grades		
	Steep hill		
	Turns		

HAZARD SIGNS

Hazard signs indicate traffic hazards and require coordination with civil authorities. Hazard signs are square and are installed in a diamond position. A military hazard sign has a yellow background and the legend or symbol in black. The symbol may also be contained within the boundaries of a red triangle. The wording on these signs is in the language or languages determined by the authority erecting the sign. Figure 4-1 contains examples of non-military signs and figure 4-2 contains examples of military signs (top sign shows a sharp turn hazard the bottom shows an intersection).

Figure 4-1. Examples of Non-military Hazard Signs

Figure 4-2. Examples of Military Hazard Signs

REGULATORY SIGNS

Regulatory signs regulate and control traffic and define areas where blackout conditions exist. Regulatory signs have a black background on which the legend or symbol is inscribed in white. Exceptions to these rules are bridge classification signs, stop signs, no entry signs, and signs that apply to civil as well as military traffic. Check with civilian authorities to ensure compliance when erecting signs in areas with civilian traffic.

The point at which a vehicle must use blackout lights is known as a light line. Light line signs are rectangular signs preceded by two warning panels placed according to the situation and nature of the terrain. Locate the first warning panel 200 to 500 meters before the light line (see figure 4-3).

Figure 4-3. Example of Regulatory Sign-Light Line

GUIDE SIGNS

Guide signs indicate direction or location. These signs consist of the military route number and the appropriate directional disk. If standard signs are not available, construct military route signs by placing a directional disk over a rectangular panel upon which the route number is inscribed (see figure 4-4).

Figure 4-4. Military Route Guide Signs

Directional Disks

A directional disk consists of a fixed black arrow, with or without a bar, on a white background. Eight equally spaced holes around the edges of the circumference allow the disk to be nailed with the arrow pointing in the desired direction. These disks are no larger than 16 inches in diameter (see figure 4-5). They are used as standard guide signs to indicate military axial and lateral routes. Directional disks may be used together with unit signs to indicate direction to locations of major units. Smaller units may not use directional disks. However, any arrow sign that provides a different shape and color from the standard direction disks can be used to indicate smaller units.

Figure 4-5. Directional Disks

Headquarters and Logistical Signs

Use these signs to mark a headquarters and logistical installations. Use the appropriate military symbol to indicate the type of unit (see MCRP 5-2A). The inscription is black on a yellow background. This symbol may be supplemented by national distinguishing symbols or abbreviations. Colors other than black or yellow are prohibited except for national distinguishing symbols.

Casualty Evacuation Route Signs

Indicate casualty evacuation routes on rectangular signs (see Figure 5-6). The signs have a white background with red inscriptions of a directional arrow, a red cross (red crescent for Turkey), and a unit or subunit designation, if required. An alternate sign may be made from a white disk with four segments cut out to give an X shape. The inscriptions are shown in red.

Figure 4-6. Casualty Evacuation Signs

Unit Direction Arrow

Use temporary unit direction arrows to mark march routes (see STANAG 2154). In addition to the direction arrow, include the unit identification symbol as part of the inscription. Unit route signs are placed in advance of the moving column and are picked up by a trail vehicle (see figure 4-7).

Figure 4-7. Unit Direction Arrow

Military Detour Signs

Detour signs consist of a white arrow inscribed on a blue square. Place the sign in a diamond position (see figure 4-8). Show the number of the diverted route by placing the number on the square over the arrow or placing the number on a small panel under the square.

Figure 4-8. Detour Signs

Route Markers in Areas of Heavy Snow

Posting route signs in areas of heavy snowfall requires additional precautions to minimize the chances of the signs being missed by personnel using the route. Ensure that the markers are placed evenly on both sides of the traveled way. In open country, use poles of appropriate height, tall enough to remain above the surface of expected snowfall. Erect markers at least one meter off the traveled way to avoid traffic damage. If you cannot completely mark a road, erect arrow signs at prominent points to indicate road direction. Road markers and signs used for long periods of time in areas of heavy snow should be checked frequently to ensure that their positions have not altered. In areas with prolonged conditions of snow, yellow (international orange) may be substituted for white on all standard military route signs.

Sign Lighting

The appropriate military authority in the area specifies which signs are to be illuminated. Primary considerations go to hazard and direction signs. The system of lighting should remain operational for a minimum of 15 hours without refueling or changing batteries. Other operational considerations are:

- Under normal conditions each commander assigned responsibility for a route must ensure that signs are visible at night and other periods of reduced visibility, taking necessary precautions in tactical situations;
- Under reduced lighting conditions, positioning of the signs and the methods adopted to make them visible (illumination or reflection) must enable personnel to see them from vehicles fitted with reduced lighting or filtering devices;
- In blackout zones, signs are equipped with upper shields that prevent light from being directly observed from the air. The light illuminating the signs is of such low intensity that it is not possible to locate the sign from the air at altitudes greater than 150 meters by its reflection off the road surface. Illumination devices are positioned so they can be recognized by oncoming vehicles at a road distance of 100 meters and read at a distance of 80 meters.

4002. BRIDGE SIGNAGE PROCEDURES FOR TRAFFIC CONTROL

All bridges in the theater of operations require classification signs. Most military equipment is heavier than common non-military loads that cross bridges. Many existing bridges are narrow, often poorly maintained, and less than the 60-70 class requirement to allow crossing of tanks. Bridges may have battle damage that has reduced their load capacity. The failure of a bridge could result in the loss of lives and equipment but could also disrupt operations throughout an AO. It is important for the equipment operators to know what the load class of the bridge and their equipment to ensure they do not use a bridge that cannot support their crossing. The bridge sign and the use of holding areas, turnouts for parking and unloading vehicles, and checkpoints provides equipment operators and traffic control personnel the necessary controls to safely utilize a bridge.

Bridge Signs

Bridge signs are circular with yellow background and black inscriptions. Sign diameters are a minimum of 16 inches for one-lane bridges and 20 inches for two-lane bridges. A two-lane bridge classification sign has two numbers, side by side, on the sign. The number on the left is the bridge classification when both lanes are in service simultaneously. The number on the right indicates the classification if the bridge is carrying one-way traffic and the vehicles proceed along the centerline of the bridge. For bridges with separate classifications for wheeled and tracked vehicles (dual classification), use a special circular sign that indicates both classifications. Classify bridges greater than class 50 as dual class bridges. Use a separate rectangular sign, if necessary, to show bridge width limitations. See Figure 4-9 for examples.

Figure 4-9. Bridge Classification Signs

Many bridges have overhead obstructions. Bridges with an overhead obstruction of less than 4.3 meters are considered obstructed for vehicles using them. The 4.3 meters is the minimum height required to pass most equipment found in military use. When overhead clearance is obstructed telltales should be installed to allow a quick visual check to confirm if a vehicle can use the bridge. A telltale is a horizontal board mounted above the road prior to crossing the bridge. If a vehicle touches the board causing it to move then it is too high the clear the overhead obstruction. Ensure the telltale is far enough from the bridge to permit the failed equipment to turnaround or pull over and adjust their loads, if possible. See figure 4-10 for an example of a telltale.

Figure 4-10. Telltale

4003. VEHICLE SIGNS AND LOAD CLASSIFICATIONS

All vehicles must be given a load classification in the theater of operations. The basis for MLC is the effect (load, vehicle speed, tire width, etc.) a vehicle has on a bridge when crossing. Heavy loads, such as artillery and tanks, make vehicles classification a very important factor when determining what can travel down a route.

Requirement for Classification Numbers

Classification numbers are mandatory for all self-propelled vehicles having a total weight of three tons or more, as well as all trailers with a payload of 1 1/2 tons or greater (see STANAGs 2010 and 2021). Trailers with a rated capacity of less than 1 1/2 tons are usually combined with their towing vehicles for classification. during the classification process, vehicles are divided into two further groups--those with trailers (vehicle combination class [CCN]) and those without (single vehicle classification number)--and calculated accordingly.

Procedures for Vehicle Classification

The actual mathematical computation of a vehicle's MLC is beyond the capability of the route reconnaissance team. However, temporary procedures are described below. MLC information is found in the vehicle's TM or on the data plate attached to the dashboard.

Procedure for Temporary Vehicle Classification

When a single vehicle tows another vehicle at a distance less than 30.5 meters and the vehicles are not designed to operate as a single unit, the temporary vehicle MLC number may be assigned to this combination. The classification number assigned is nine-tenths the sum of the normal vehicle classification numbers if the total of both classifications is less than 60. If the sum of the two military classification numbers is 60 or over, then the total becomes the MLC number for the nonstandard combination.

CCN = 0.9 (A + B) if A + B < 60 or CCN = A + B if A + B >= 60

where A = Class of first vehicle and B = Class of second vehicle

Expedient Procedure for Wheeled-Vehicle Classification

It will often be necessary to classify a vehicle in the field. Simply observe and compare the unclassified vehicle to a vehicle that is similar. Compare the axle loads, gross weight, and dimensions of the unclassified vehicle with those of a similar classified vehicle.

> **Example:** The expedient classification for a wheeled vehicle is estimated to be 85 percent of its total weight. Therefore, you must determine the vehicle's gross weight. Multiply the air pressure in the tires (in pounds per square inch [psi]) by the total area (in square inches) of the tires in contact with the ground. If a gage is not available, use 75 psi as an average value. This yields an approximate weight of the vehicle in pounds. Convert this figure to tons (2000 pounds per ton) and find 85 percent of the weight in tons. This resulting figure is the expedient classification.

Expedient Procedure for Tracked-Vehicle Classification

Tracked vehicles weigh about one ton per square foot of track in contact with the ground (one square foot equals 144 square inches). By determining the area of track in contact with the ground, the vehicle's gross weight can be assigned. In the case of vehicles that weigh a fraction over whole tonnage, the next higher classification number is assigned.

Vehicle Signs

There are two types of vehicle signs: front and side. Use front signs on all vehicles, except trailers, to show the classification of the laden vehicle. Use side signs on towing vehicles and trailers only to show the classification of the laden towing vehicles or trailers by themselves.

Both signs are circular and marked in contrasting colors consistent with camouflage requirements. Black figures on a yellow background may be used. The front sign is 23 centimeters in diameter and the side sing is 15 centimeters in diameter.

Place or paint the front sign on the front of the vehicle, above or on the bumper, and below the driver's line of vision. When possible, place it on the right side, facing forward. Place or paint the side sign on the vehicle's right side facing outward.

Make the inscription on the sign as large as the sign allows. The front sign--except on towing vehicles and tank transporters--indicates the vehicle's laden solo class. On towing vehicles, the front sign indicates the train's combined load class. Above this number, write the letter "C" to distinguish the vehicle as a towing vehicle. On tank transporters and similar type vehicles, the fixed front sign shows the maximum classification of the laden vehicle. In addition, one alternate front sign may be carried. Place it so it covers the fixed front sign, when necessary, to show the class of the vehicle when unladen. The side sign (used only by prime movers of combination vehicles and trailers) indicates the laden solo class of the prime mover or trailer. See figure 4-11 for example of a vehicle sign.

Figure 4-11. Vehicle Sign

Appendix A

Metric Conversion Chart

This appendix provides conversion factors for engineers when conversion form metric to U.S. or U.S. to metric is necessary.

US Units	Multiplied By	Metric Units
Acres	0.49	Hectares
Cubic feet	0.03	Cubic meters
Cubic inches	16.39	Cubic centimeters
Cubic inches	0.02	Liters
Cubic yards	0.76	Cubic meters
Feet	0.3	Meters
Feet per second	18.29	Meters per second
Gallons	3.79	Liters
Inches	2.54	Centimeters
Inches	0.03	Meters
Inches	25.4	Millimeters
Miles	1.61	Kilometers
Square feet	0.09	Square meters
Square inches	6.45	Square centimeters
Square miles	2.59	Square kilometers
Square yards	0.84	Square meters
Yards	0.91	Meters
Metric Units	**Multipied by**	**US Units**
Centimeters	0.39	Inches
Cubic centimeters	0.06	Cubic inches
Cubic meters	35.31	Cubic feet
Cubic meters	1.31	Cubic yards
Kilometers	0.62	Miles
Meters	3.28	Feet
Meters	39.37	Inches
Meters	1.09	Yards
Millimeters	0.04	Inches
Square centimeters	0.16	Square inches
Square kilometers	0.39	Square miles
Square meters	1.2	Square yards
Square meters	10.76	Square feet

Appendix B

Blanks of Six Common Engineer Forms and Radio Reports

These six common forms and radio reports are routinely utilized by engineers in the performance of the missions. Additional information concerning these forms and other useful engineering forms can be found in MCRP 3-17B, Engineer Forms and Reports.

AI
RFI
EL
D
RE
PO
RT

AI
R
LA
ND
IN
G
AR
EA
RE
PO
RT

GOLF	Type of soil
HOTEL	Availability of areas suitable for dispersal

AI
RS
T
RI
P
R
EP
O
R
T

A
M
P
HI
BI
O
U
S
C
R
O
SS
IN
G
SI
TE REPORT

ALPHA	Map sheet(s)

BRIDGE REPORT

	demolition, type and condition of abutments.

BRIDGE SITE REPORT

COM

BAT ROUTE SITE

ALPHA	Map sheet(s)

DAM AND SLUICE REPORT

ECHO	Dimensions (length, height, thickness at top and bottom)

ENEMY AND/OR UNIDENTIFIED MINEFIELD REPORT

ECHO	Depth of minefield
FOXTROT	Estimated time required to clear the minefield
GOLF	
HOTEL	Estimated material and equipment required to clear the minefield
INDIA	Routes for bypassing the minefield, if any.
JULIETT through YANKEE	Grid reference of lanes (entry and exit) and width of lanes, in meters
ZULU	Additional information such as types of mines and fusing, description of unknown mine types, and boobytraps

1 ENEMY STORES AND EQUIPMENT REPORT

ALPHA	Map sheet(s)
BRAVO	Date and time information was collected
CHARLIE	Location (grid coordinates)
DELTA	Type (ammunition, vehicles, etc.)
ECHO	Quantity
FOXTROT	Condition
GOLF	Additional information

2 FERRY SITE REPORT

ALPHA	Map sheet(s)
BRAVO	Date and time information was collected
CHARLIE	Location (grid coordinates)
DELTA	Trafficability of near and far shore routes (GO, SLOW-GO, NO GO)
ECHO	Possibilities for concealment or cover
FOXTROT	Width of river
GOLF	Depth of water long ferry path and at the banks, including tidal information
HOTEL	Stream velocity
INDIA	Maximum slope on bank approaches and bank conditions

JULIETT	Parking areas for road and water transport
KILO	Any other information which could be given, such as maximum number of rafts for which site is usable, personnel hours required for preparation of approach routes, present water gauge reading (if available) and obstructions or restrictions at the site

FORD REPORT

ALPHA	Map sheet(s)
BRAVO	Date and time information was collected
CHARLIE	Location (grid coordinates)
DELTA	Minimum width
ECHO	Minimum depth
FOXTROT	Stream Velocity
GOLF	Type of bottom; for example, SOFT SANDY or FIRM ROCKY
HOTEL	Maximum slope on banks and bank condition; for example, 9 percent-SLIPPERY CLAY
INDIA	Trafficability of near/far shore (GO, SLOW-GO, NO-GO)
JULIETT	Rise and fall of water level
KILO	Concealment/cover
LIMA	Any other information that could be given, such as essential limiting features or requirements for support

FRIENDLY OBSTACLE REPORT

ALPHA	Map sheet(s)
BRAVO	Date and time information was collected
CHARLIE	Location (grid coordinates)
DELTA	Type of obstacle
ECHO	Status of work
FOXTROT	Any other information

INSTALLATION REPORT

ALPHA	Map sheet(s)
BRAVO	Date and time information was collected
CHARLIE	Location (grid coordinates)
DELTA	Type of installation
ECHO	Capacity, including shelter or storage
FOXTROT	Condition

GOLF	Additional information

LOCAL RESOURCES REPORT

ALPHA	Map sheet(s)
BRAVO	Date and time information was collected
CHARLIE	Location (grid coordinates)
DELTA	Type
ECHO	Quantity of stock
FOXTROT	Capacity and/or output per day
GOLF	Additional information

OBSTACLE REPORT

ALPHA	Map sheet(s)
BRAVO	Date and time information was collected
CHARLIE	Location (grid coordinates)
DELTA	Type of obstacle
ECHO	Enemy weapons having coverage of obstacle, if any.
FOXTROT	Any other information that could impact on breaching or bypass; for example, terrain restricts bypass, work required (in personnel hours) to breach obstacle

PORT REPORT

ALPHA	Map sheet(s)
BRAVO	Date and time information was collected
CHARLIE	Location (grid coordinates)
DELTA	Environmental data. (1) Tides, (2) Winds, (3)

	Harbor obstructions, (4) Navigational aids, (5) Depth of main channel
ECHO	Tug/pilot services
FOXTROT	Berths and/or anchorages. (1) Type (concrete, stone, wood, earthen retained by seawall, etc., (2) Length and width, (3) Single or double sided berthing, (4) Low tide depth at pierside, (5) Maximum load capacity
GOLF	Pierside services. (1) Materials handling equipment (cranes, forklifts, etc.), (2) Covered and exposed warehouse space in square and cubic footage, (3) Office/administrative facilities
HOTEL	Refueling and fuel storage facilities
INDIA	Firefighting facilities
JULIETT	Vehicle staging areas. (1) Size in square feet, (2) Surface material (paved, gravel, etc.), (3) Access routes, (4) Distance from berthing areas
KILO	Access roads. (1) Classification, (2) Surface material
LIMA	Helicopter landing areas (location[s] and capacity)
MIKE	Airfields (location[s], submit appropriate airlanding site report)
NOVEMBER	Railroad facilities and rolling stock available
OSCAR	Additional information

ROAD(S) CLOSED REPORT

ALPHA	Map sheet(s)
BRAVO	Date and time information was collected
CHARLIE	From grid reference
DELTA	To grid reference
ECHO	Reason for closing of road (bridge destroyed at grid reference, unusable by heavy traffic)
FOXTROT	Estimated duration
GOLF	Detour from _______ to ______ including, if possible, class of road, or at least the following information: width of road, smooth or rough surface, gradual or sharp curves, gentle or steep grades. Classification of roads is to be given according to the weakest part of a section of road under report; that is, the class of the entire road may be restricted by a single bridge with a low military load class.
HOTEL	Cross-country bypass permitted to _____ (wheeled or tracked vehicles, and class).
INDIA	Any other information

1 ROAD(S) OPENED REPORT

ALPHA	Map sheet(s)
BRAVO	Date and time information was collected
CHARLIE	From grid reference
DELTA	To grid reference
ECHO	Class of road and characteristics of the road to include information on shoulders. Classification of roads is given according to the weakest part or section of road under report; as an example, the class of the entire route may be by the low class of a single bridge
FOXTROT	Minimum widths

2 ROUTE CLOSED REPORT

ALPHA	Map sheet(s)
BRAVO	Date and time information was collected
CHARLIE	From grid reference
DELTA	To grid reference
ECHO	Reason for route closure (bridge destroyed at grid reference, unusable by heavy traffic)
FOXTROT	Estimated duration
GOLF	Detour from _______ to ______ including, if possible, military load classification of detour, widths, smooth or rough surface, gradual or sharp curves, gentle or steep grades.
HOTEL	Cross-country bypass permitted for _____ (wheeled or tracked vehicles, and class).
INDIA	Any other information

3 ROUTE OPENED REPORT

ALPHA	Map sheet(s)
BRAVO	Date and time information was collected
CHARLIE	From grid reference
DELTA	To grid reference
ECHO	Military load classification of route.
FOXTROT	Minimum widths

1 TERRAIN REPORT

ALPHA	Map sheet and grid references (four grid coordinates to outline area reconnoitered)
BRAVO	Shape of ground, for example, flat, rolling, hilly, swampland, or mountainous
CHARLIE	Cross-country movement (GO, SLOW-GO, or NO GO)
DELTA	Vegetation (type and restrictions, if any)
ECHO	Concealment available
FOXTROT	Land use (rice paddies, plowed but unplanted, wheat fields, and so forth)
GOLF	Suitability of soil for digging, for example, good (no rocks), poor (rocky, clay), and difficult-depending on existing weather conditions
HOTEL	Weather at time of report (dry, wet, frozen, etc.)

2 TRANSFER OF MINEFIELD/OBSTACLE REPORT

ALPHA	Map sheets
BRAVO	Location (grid coordinates)
CHARLIE	I.D. number of obstacle
DELTA	Transfer from (unit)
ECHO	Transfer to (unit)

3 TUNNEL REPORT

ALPHA	Map sheet(s)
BRAVO	Date and time information was collected
CHARLIE	Location (grid coordinates)
DELTA	Length
ECHO	Width at most constricted diameter
FOXTROT	Height at minimum height location
GOLF	Gradient
HOTEL	Type of tunnel (railroad, vehicle, footpath)
INDIA	Condition
JULIETT	Bypass route(s) available
KILO	Any other information that could impact trafficability including shape of tunnel bore

WATER POINT REPORT

ALPHA	Map sheet(s)
BRAVO	Date and time information was collected
CHARLIE	Location (grid coordinates)
DELTA	Type (well, spring, watercourse, lake, pond)
ECHO	Rate of delivery of water
FOXTROT	Total quantity of water available and description of water source (salty, clear, muddy, polluted, etc.)
GOLF	Existing pumping and storage facilities
HOTEL	Accessibility
INDIA	Additional information

Appendix C

Common Symbols

Table C-1 identifies symbols used in reconnaissance missions. Other sources of symbols are MCRP 5-2A, Operational Terms and Graphics, and FM 5-34, Engineer Field Data.

Table C-1. Reconnaissance symbols

Symbol	Definition
	Abbreviated bridge symbol. Use this symbol only when the map scale does not permit the use of the full NATO bridge symbol. Submit DA Form 1249 if this symbol is used. Draw an arrow to the map location of the bridge. Show the bridge's serial number in the lower portion of the symbol and the MLC for single-flow traffic in the upper portion. If there are separate load classifications for tracked or wheeled vehicles, show the lesser classification. Underline the classification number if the width or overhead clearance is below minimum requirements.
	Concealment. Show roads lined with trees by a single line of circles for deciduous trees and a single line of inverted Vs for evergreen trees. Show woods bordering a road by several rows of circles for deciduous trees and several rows of inverted Vs for evergreen trees.
	Critical points. Number (in order) and describe critical points on DA Form 1711-R. Use critical points to show features not adequately covered by other symbols on the overlay.
	Ferry. See Chapter 5 for a complete discussion.
	Ford. See Chapter 5 for a complete discussion.
	Full NATO bridge symbol. See Chapter 4 for complete discussion.
	Grades. See Chapter 5 for a complete discussion.
	Limits of sector. Show the beginning and ending of a reconned section of a route with this symbol.
	Parking area.
	Railway bridge symbol. Place RL above the symbol to indicate a railway bridge. At the left of the symbol, show the overhead clearance. Show the bridge's overall length at the

	right of the symbol. Indicate the traveled-way width below the symbol and underline it if it is below standard for the classification. Inside the symbol, show the bridge classification in the upper half. If the class is different for single-and double-flow traffic, show single flow on the left and double flow on the right. Place the railway bridge's serial number in the lower half of the symbol. Draw an arrow to the map location of the bridge. On the arrow shaft, indicate the ease of adapting the bridge for road-vehicle use. A zigzag line means it would be difficult to adapt; a straight line means it would be easy to adapt. Place the bypass symbol on the arrow shaft to indicate bypass conditions.
	Railroad grade crossing. Use this symbol to show a level crossing where passing trains would interrupt traffic flow. If there is a power line present, show its height (in meters) from the ground. Underline the overhead clearance if it is less than 4.3 meters.
10.5 m/X/120/00 6 m/Z/30/4.1 m 9 m/V/40/5 m (OB)(W)	*Route-classification formula.* See Chapter 5 for a complete discussion.
	Series of sharp curves. See Chapter 5 for a complete discussion.
	Sharp curve. See Chapter 5 for a complete discussion.
	Tunnel. See Chapter 5 for a complete discussion.
	Turnout. Use this symbol to show the possibility of driving off the road. Draw the arrow in the direction of the turnout (right or left of the road). For wheeled vehicles, draw a small circle on the arrow's shaft. For tracked vehicles, draw a small square on the arrow's shaft and place the length of the turnout, in meters, at the tip of the arrow. When a turnout is longer than 1 kilometer, use double arrows.
	Underpass constriction. See Chapter 5 for a complete discussion.
	Width constriction. The number on the left shows the narrowest width of the constriction; the number on the right is the total constricted length. Both dimensions are in meters.

1

Engineer Resource Symbols

Appendix D

Table D-1. Variable Notations and Definitions

Variable	**Definition**
b	Stringer width in inches
b_d	Concrete slab width in feet
b_e	Effective slab width in feet
b_{e1}	Effective slab width for one-lane traffic in feet
b_{e2}	Effective slab width for two-lane traffic in feet
b_R	Curb to curb roadway width in feet
d	Stringer depth in inches
d_f	Depth of fill in inches
d_i	Interior stringer depth ($d-2_{tf}$) in inches
f_{bDL}	Allowable bearing stress of the stringer in ksi
L	Span length in feet
L_c	Maximum brace spacing in feet
L_m	Maximum span length in feet
m	Moment capacity per stringer in kip-feet
m_{DL}	Dead-load moment per stringer in kip-feet
M_{DL}	Dead-load moment for entire span in kip-feet
m_{LL}	Live-load moment per stringer in kip-feet
M_{LL}	Live-load moment per lane in kip-feet
M_{LL1}	Live-load moment for one-lane traffic in kip-feet
M_{LL2}	Live-load moment for two-lane traffic in kip-feet
N_b	Number of braces
N_L	Number of lanes
N_S	Total number of stringers in the span
N_1	Effective number of stringers for one-lane traffic
N_2	Effective number of stringers for two-lane traffic
P_{LC}	Provisional load class
R	Rise of arch in feet
S	Section modulus in cubic inches
S_b	actual brace spacing in feet
S_c	Section modulus of the composite section in cubic inches
S_S	Center to center stringer spacing in feet
t_c	Crown thickness
t_d	Average deck thickness in inches
t_{eff}	Effective deck thickness in inches
t_f	Flange thickness in inches
t_{pl}	Plate thickness in inches
t_w	Web thickness in inches
t_x	Thickness factor
T_1	One-lane tracked vehicle classification
T_2	Two-lane tracked vehicle classification
v	Shear capacity per stringer in kips
v_{DL}	Dead load shear per stringer in kips
V_{DL}	Estimate dead-load shear of span in kips
v_{LL}	Live-load shear per stringer in kips
V_{LL}	Live-load shear per lane in kips
W_s	Stringer weight in lbs/ft
W_1	One-lane wheeled vehicle classification
W_2	Two-lane wheeled vehicle classification
X_{pl}	Plate thickness factor
%lam	Percent of lamination

Table D-2. Properties of Round and Rectangular Timber Stringers

	Rectangular	Stringers			Round	Stringers	Nominal size is Diameter
Nominal Size (b x d, in)[1]	m (kip-ft)[2]	v (kips)[3]	$L_{m(ft)}$[4]	Nominal Size (b x d, in)[1]	m (kip-ft)[2]	v (kips)[3]	$L_{m(ft)}$[4]
4 x 6	4.8	2.4	7.14	8	10.05	5.7	9.5
4 x 8	8.53	3.2	9.5	9	14.31	7.2	10.7
4 x 10	13.33	4	11.9	10	19.63	8.8	11.9
4 x 12	19.2	4.8	14.3	11	26.1	10.6	13.1
6 x 8	12.8	4.8	9.5	12	33.9	12.7	14.3
6 x 10	20	6	11.9	13	43.1	15	15.5
6 x 12	28.8	7.2	14.3	14	53.9	17.4	16.7
6 x 14	39.2	8.4	16.7	15	67.5	20.2	17.8
6 x 16	51.2	9.6	19.1	16	80.4	22.6	19.1
6 x 18	64.8	10.8	21.5	17	98.2	26	20.2
8 x 8	17.07	6.4	9.5	18	114.5	28.6	21.5
8 x 10	26.7	8	11.9	19	137.1	32.4	22.6
8 x 12	38.4	9.6	14.3	20	157.1	35.4	23.8
8 x 14	52.3	11.2	16.7	21	185.2	39.6	24.9
8 x 16	68.3	12.8	19.1	22	209	42.7	26.2
8 x 18	86.4	14.4	21.5	23	243	47.6	27.3
8 x 20	106.7	16.4	23.8	24	271	50.8	28.6
8 x 22	129.1	17.6	26.2	25	312	56.2	29.7
8 x 24	153.6	19.2	28.6	26	351	60.8	30.9
10 x 10	33.3	10	11.9	27	393	65.6	32.1
10 x 12	48	12	14.3	28	439	70.5	33.3
10 x 14	65.3	14	16.7	29	487	75.6	34.5
10 x 16	85.3	16	19.1	30	540	81	35.7
10 x 18	108	18	21.5	31	595	86.4	36.8
10 x 20	133.3	20	23.8	32	655	92.1	38
10 x 22	161.3	22	26.2	33	718	98	39.2
10 x 24	192	24	28.6	34	786	104	40.4
12 x 12	57.6	14.4	14.3	35	857	110.2	41.6
12 x 14	78.4	16.8	16.7	36	933	116.6	42.8
12 x 16	102.4	19.2	19.1				
12 x 18	129.6	21.6	21.5				
12 x 20	160	24	23.8				
12 x 22	193.6	26.4	26.2				
12 x 24	230	28.8	28.6				
14 x 14	91.5	19.6	16.7				
14 x 16	119.5	22.4	19.1				
14 x 18	151.2	25.2	21.5				
14 x 20	186.7	28	23.8				
14 x 22	226	30.8	26.2				
14 x 24	269	33.6	28.6				
16 x 16	136.5	25.6	19.1				
16 x 18	172.8	28.8	21.5				
16 x 20	213	32	23.8				
16 x 22	258	35.2	26.2				
16 x 24	307	38.4	28.6				
18 x 18	194.4	32.4	21.5				
18 x 20	240	36	23.8				
18 x 22	290	9.6	26.2				
18 x 24	346	43.2	28.6				

[1] If $d > 2b$, bracing is required at the midspan and at both ends.

[2] Moment capacity for rectangular stringers not listed is $bd^2/30$. Moment capacity for round stringers not listed is $0.02d^3$.

[3] Shear capacity for rectangular stringers not listed is $bd/10$. Shear capacity for round stringers not listed is $0.09d^2$.

[4] Maximum span length for stringers not listed is $1.19d$.

Table D-3. Properties of Steel Stringers

(Fy=36 ksi, fb=27 ksi, fv=16.5 ksi)

Nominal Size	d (in)	b (in)	T_f (in)	t_w (in)	m (kip-ft)	v (kips)	L_m (ft)	L_c (ft)
W39 x 211	39.25	11.75	1.44	0.75	1,770	450	100	12.4
W37 x 206	36.75	11.75	1.44	0.75	1,656	425	95	12.4
W36 x 300	36.75	16.63	1.69	0.94	2,486	520	94	17.6
W36 x 194	36.5	12.13	1.25	0.81	1,492	431	93	12.8
W36 x 182	36.38	12.13	1.19	0.75	1,397	406	93	12.8
W36 x 170	36.13	12	1.13	1.06	1,302	381	92	12.7
W36 x 160	36	12	1	1.06	1,217	365	92	12.7
W36 x 230	35.88	16.5	1.25	0.75	1,879	421	91	17.4
W36 x 150	35.88	12	0.94	0.62	1,131	350	91	12.7
W36 x 201	35.38	11.75	1.44	0.75	1,545	402	90	12.4
W33 x 196	33.38	11.75	1.44	0.75	1,433	377	85	12.4
W33 x 220	33.25	15.75	1.25	0.81	1,661	392	85	16.6
W33 x 141	33.25	11.5	0.94	0.62	1,005	313	85	12.1
W33 x 130	33.13	11.5	0.88	0.56	911	300	85	12.1
W33 x 200	33	15.58	1.13	0.56	1,506	362	84	16.6
W31 x 180	31.5	11.75	1.31	0.75	1,327	327	80	12.4
W30 x 124	30.13	10.5	0.94	0.68	797	273	77	11.1
W30 x 116	30	10.5	0.88	0.62	738	263	76	11.1
W30 x 108	29.88	10.5	0.75	0.56	672	255	76	11.1
W30 x 175	29.5	11.75	1.31	0.56	1,156	304	75	12.4
W27 x 171	27.5	11.75	1.31	0.68	1,059	282	70	12.4
W27 x 102	27.13	10	0.81	0.68	599	217	69	10.6
W27 x 94	26.88	10	0.75	0.5	546	205	68	10.6
W26 x 15	25.5	11.75	1.25	0.5	915	237	65	12.4
W24 x 94	24.25	9	0.88	0.62	497	191	62	9.5
W24 x 84	24.13	9	0.75	0.5	442	174	61	9.5
W24 x 100	24	12	0.75	0.5	560	173	61	12.7
S24 x 120	24	8	1.13	0.5	564	286	61	8.4
S24 x 106	24	7.88	1.13	1.18	527	224	61	8.3
S24 x 80	24	7	0.88	0.62	391	183	61	7.4
W24 x 76	23.88	9	0.69	0.5	394	163	61	9.5
W24 x 153	23.63	11.75	0.25	0.43	828	217	60	12.4
S24 x 134	23.63	8.5	1.25	0.62	634	283	60	9
S22 x 75	22	7	0.81	0.81	308	168	56	7.4
W21 x 139	21.63	11.75	1.19	0.5	699	198	55	12.4
S21 x 112	21.63	7.88	1.19	0.62	495	238	55	8.3
W21 x 73	21.25	8.25	0.75	0.75	338	148	54	8.7
W21 x 68	21.13	8.25	0.69	0.5	315	140	54	8.7
W21 x 62	21	8.25	0.63	0.43	284	130	53	8.7
S20 x 85	20	7.13	0.94	0.37	337	195	51	7.5
S20 x 65	20	6.5	0.81	0.68	245	132	51	6.9
W20 x 134	19.63	11.75	1.19	0.43	621	177	50	12.4
W18 x 60	18.25	7.5	0.69	0.62	243	115	46	7.9
S18 x 86	18.25	7	1	0.43	326	184	46	7.4
W18 x 55	18.13	7.5	0.63	0.37	220	108	46	7.9
S18 x 80	18	8	0.94	0.5	292	133	46	8.4
W18 x 50	18	7.5	0.56	0.37	200	99	46	7.9
S18 x 55	18	6	0.69	0.5	199	126	46	6.3
S18 x 122	17.75	11.75	1.06	0.56	648	145	45	12.4
S18 x 62	17.75	6.88	0.75	0.37	238	100	45	7.3
S18 x 77	17.75	6.63	0.94	0.62	281	163	45	7
W16 x 112	16.75	11.75	1	0.56	450	136	42	12.4

S16 x 70	16.75	6.5	0.94	0.62	238	146	42	6.9
W16 x 50	16.25	7.13	0.63	0.37	181	94	41	7.5
W16 x 45	16.13	7	0.56	0.37	163	85	41	7.4
W16 x 64	16	8.5	0.69	0.43	234	106	40	9
W16 x 40	16	7	0.5	0.31	145	75	40	7.4
S16 x 50	16	6	0.69	0.43	155	105	40	6.3
W16 x 36	15.88	7	0.44	0.31	127	74	40	7.4
W16 x 110	15.75	11.75	1	0.56	345	127	40	12.4
S16 x 62	15.75	6.13	0.88	0.56	200	129	40	6.5
S16 x 45	15.75	5.38	0.63	0.43	150	104	40	5.7
W15 x 103	15	11.75	0.94	0.56	369	121	38	12.4
S15 x 56	15	5.88	0.81	0.5	173	110	38	6.2
S15 x 43	15	5.5	0.63	0.43	132	93	38	5.8
W14 x 101	14.25	11.75	0.94	0.56	344	114	36	12.4
S14 x 40	14.25	5.38	0.38	0.37	119	83	36	5.7
S14 x 51	14.13	5.63	0.75	0.5	150	104	36	5.9
S14 x 70	14	8	0.94	0.43	204	87	35	8.4
S14 x 57	14	6	0.88	0.5	153	101	35	6.3
W14 x 34	14	6.75	0.44	0.31	121	78	35	7.1
W14 x 30	13.88	6.75	0.38	0.25	109	61	35	7.1
W14 x 92	13.38	11.75	0.88	0.5	297	96	34	12.4
S14 x 46	13.38	5.38	0.69	0.5	126	99	34	5.7
S13 x 35	13	5	0.63	0.37	85	72	33	5.3
S13 x 41	12.63	5.13	0.69	0.37	108	104	32	5.4
W12 x 36	12.25	6.63	0.56	0.31	103	56	31	7
S12 x 65	12	8	0.94	0.43	182	73	30	8.4
W12 x 27	12	6.5	0.38	0.25	76	44	30	6.9
S12 x 50	12	5.5	0.69	0.68	113	120	30	5.8
S12 x 32	12	5	0.56	0.37	81	62	30	5.3
S12 x 34	11.25	4.75	0.63	0.43	81	72	28	5
W11 x 76	11	11	0.81	0.5	202	67	28	11.6
S10 x 29	10.63	4.75	0.56	0.31	67	48	27	5
W10 x 25	10.13	5.75	0.44	0.25	59	38	25	6.1
S10 x 40	10	6	0.69	0.37	92	53	25	6.3
S10 x 35	10	5	0.5	0.62	65	88	25	5.3
S10 x 25	10	4.63	0.5	0.31	55	46	25	4.9
W10 x 21	9.88	5.75	0.31	0.25	48	36	25	6.1
W10 x 59	9.25	9.5	0.69	0.43	132	56	25	10
S9 x 25	9.5	4.5	0.5	0.31	51	43	24	4.8
S9 x 50	9	7	0.81	0.37	103	45	23	7.4
S8 x 35	8	6	0.63	0.31	65	34	20	6.3
S8 x 28	8	5	0.56	0.31	49	35	20	5.3
W8 x 31	8	8	0.44	0.31	61	33	20	8.4
W8 x 44	7.88	7.88	0.63	0.75	81	40	20	8.3
W7 x 35	7.13	7.13	0.56	0.37	58	37	18	7.5
W6 x 31	6.25	6.25	0.56	0.37	45	31	16	6.6

Table D-4. Dead-load Moment and Shear

L (ft)	Timber Stringer/Timber Deck				Steel Stringer/Timber Deck			
	One-Lane		Two-Lane		One-Lane		Two-Lane	
	M_{DL} (kip-ft)	V_{DL} (kips)	M_{DL} (kip-ft)	V_{DL} (kips)	M_{DL} (kip-ft)	V_{DL} (kips)	M_{DL} (kip-ft)	V_{DL} (kips)
70					649.26	37.1	1,133.13	64.75
65					538.68	33.15	937.42	57.69
60					441	29.4	765	51
55					355.44	25.85	614.45	44.69
50					281.25	22.5	484.38	38.75
45					217.69	19.35	373.36	33.19
40					164	16.4	280	28
38					145.12	15.28	247.85	26.03
36					127.66	14.18	217.08	24.12
34					111.55	13.12	189.3	22.27
32					96.77	12.1	163.84	20.48
30	91.13	12.15	160.8	21.45	83.25	11.1	140.63	18.75
28	76.24	10.89	134	19.15	70.95	10.14	119.56	17.08
26	63.04	9.7	110.3	16.98	59.83	9.2	100.56	15.47
24	51.41	8.57	89.57	14.93	49.82	8.3	83.52	13.92
22	41.26	7.5	71.51	13	40.9	7.44	68.37	12.43
20	32.5	6.5	56	11.2	33	6.6	55	11
18	25.03	5.56	42.85	9.52	26.1	5.8	43.34	9.63
16	18.75	4.89	31.87	7.97	20.1	5.02	33.28	8.32
14	13.57	3.88	22.88	6.54	14.99	4.28	24.75	7.07
12	9.4	3.13	15.7	5.23	10.73	3.58	17.64	5.88
10	6.13	2.45	10.13	4.05	7.25	2.9	11.88	4.75
9	4.8	2.13	7.89	3.51				
8	3.66	1.83	5.98	2.99				

Table D-5. Profile Factors

Serial No.	**Span to Rise Ratio**	**Factor**	**Remarks**
1	Up to 4	1	For a given load, a flat arch of steeper profile (although is has a very large rise) may fail due to the crown's action as a smaller, flatter arch.
2	Over 4	See Figure 5-11	

Table D-6. Arch Factors

Material Factors		
Serial No.	**Type of Material**	**Fact**
1	Granite, white stone, or built-in course masonry	1.5
2	Concrete or blue engineering bricks	1.2
3	Good limestone masonry and building bricks	1
4	Poor masonry or any kind of brickwork	0.70 -
Joint Factors		
Type of Joint		
1	Thin joints, 1/10 inch or less in width	1.2
2	Normal joints, width to 1/4 inch, pointed mortar	1
3	Normal joint, mortar unpointed	0.9
4	Joint over 1/4 inch, irregular good mortar	0.8
5	Joint over 1/4 inch, mortar with voids deeper than 1/10 of the ring thickness	0.7
6	Joints 1/2 inch or more, poor mortar	0.5

Deformations			
	Condition	**Adjustment**	**Note**
1	The rise over the affected portion is always positive.	Discard profile factor already calculated and apply span-to-rise ratio of affected portion to whole arch.	Arch ring deformation may be due to partial failure of the ring (usually accompanied by a sag in the parapet) or movement at the abutment.
2	Distortion produces a flat section of profile.	Maximum MLC=12.	
3	A portion of the ring is sagging.	Maximum MLC=5 only if fill at crown > 18 inches.	

Abutment Size Factors			
	Type of Abutment	**Factor**	**Note**
1	Both abutments satisfactory	1	An abutment may be regarded as inadequate to resist the thrust of the arch if -- 1. The bridge is on a narrow embankment, particularly if the approaches slope steeply up to the bridge.
2	One abutment unsatisfactory	0.95	
3	Both abutments unsatisfactory	0.9	2. The bridge is on an embanked curve.
4	Both abutments massive but a clay fill suspected	0.7	
5	Arch carried on one abutment and one pier	0.9	3. The abutment walls are very short and suggest

			little solid fill behind the arch.
6	Arch carried on two piers	0.8	

Abutment Fault Factors

	Type of Fault	Fac
1	Inward movement of one abutment	0.75 -
2	Outward spread of abutments	1.00 -
3	Vertical settlement of one abutment	0.90 -

Crack Factors

	Type of Crack	Factor	Note
1	Longitudinal cracks within 2 feet of the edge of the arch; if wider than 1/4 inch and longer the 1/10 of the span in bridges: 1. Wider than 20 feet between parapets; 2. Narrower than 20 feet between parapets.	 1.00 0.90 - 0.70	Due to an outward force on the spandrel walls caused by a lateral spread of the fill.
2	Longitudinal cracks in the middle third of the ridge with -- 1. One small crack under 1/8 inch wide and shorter than 1/10 of the span; 2. Three or more small cracks as above; 3. One large crack wider than 1/4 inch and longer than 1/10 of the span.	 1.00 0.50 0.50	Due to varying amount of subsiding along the length of the abutment; large cracks are danger signs which indicate that the arch ring has broken up into narrower, independent rings.
3	Lateral and diagonal cracks less than 1/8 inch wide and shorter than 1/10 of the arch width	1	Lateral cracks, usually found near the quarter points, are due to permanent deformation of the arch, which may be caused by a partial collapse of the arch or abutment movement. Diagonal cracks, usually starting near the sides of the arch springing and spreading toward the center of the arch at the crown, are probably due to subsiding at the sides of the abutment.
4	Lateral and diagonal cracks wider than 1/4 inch and longer than 1/10 of the arch width: restrict load class to 12 or to the calculated class using all other applicable factors, whichever is less.		
5	Cracks between the arch ring and spandrel or parapet wall greater than 1/10 of the span due to fill spread	0.9	Cracks indicate that the bridge is in a dangerous condition due to spreading of the fill pushing the wall outward or movement of a flexible ring away from a stiff fill, so that the two act independently. The latter type of failure often produces cracks in the spandrel wall near the
6	Cracks between the arch ring and spandrel or parapet wall due to a dropped ring; reclassify from the nomograph, taking the crown thickness as that of the ring alone.		

			quarter points.

Table D-7. Section Moduli for Composite Steel Stringers

Nominal Size	**d (in)**	**b (in)**	**S_c (cu in) td=3"**	**S_c (cu in) td=4"**	**S_c (cu in) td=5"**	**S_c (cu in) td=6"**	**S_c (cu in) td=8"**
W36 x 300	36.75	16.63	1,105	1,264	1,323	1,380	1,489
W36 x 230	35.88	16.5	835	972	1,018	1,061	1,145
W36 x 194	36.5	12.13	663	805	847	887	961
W36 x 182	36.38	12.13	621	757	796	833	902
W36 x 170	36.13	12	579	709	745	779	844
W36 x 160	36	12	541	667	701	733	794
W36 x 150	35.88	12	502	624	656	686	744
W33 x 220	33.88	15.75	740	868	910	951	1,031
W33 x 200	33.63	15.75	669	789	828	865	938
W33 x 141	33.25	11.5	446	555	585	612	666
W33 x 130	33.13	11.5	404	509	536	561	612
W30 x 172	30.5	15	528	630	663	694	757
W30 x 124	30.13	10.5	354	449	474	497	546
W30 x 116	30	10.5	327	419	442	464	511
W30 x 108	29.88	10.5	299	387	409	429	473
W27 x 161	27.63	14	455	537	566	595	655
W27 x 102	27.13	10	267	342	362	381	423
W27 x 94	26.88	10	243	315	333	350	390
W27 x 84	26.75	10	213	279	295	311	347
W24 x 94	24.25	9.13	222	288	306	323	364
W24 x 84	24.13	9	196	258	274	290	326
W24 x 76	23.88	9	176	233	247	262	295
W21 x 73	21.25	8.25	151	203	216	231	263
W21 x 68	21.13	8.25	140	189	202	216	246
W21 x 62	21	8.25	127	172	184	197	224
W18 x 60	18.25	7.5	108	149	160	173	201
W18 x 55	18.13	7.5	98	137	147	159	184
W18 x 50	18	7.5	89	124	134	145	168

Table D-8. Deck Thickness Factors for Allowable Live-load Moment

t_d (in)	**t_x**	**t_d (in)**	**t_x**
4	1	8	1.2
5	1.05	9	1.25
6	1.1	10	1.3
7	1.15		

Figure D-1. Timber Deck Classification

Figure D-2. Profile Factors for Arch Bridges

Figure D-3. Live-load Moment for a 12 inches Reinforced Concrete Strip

Figure D-4. Masonry Arch PLC

Figure D-5. Bridge Class

Figure D-6. Live-load Moment for Wheeled Vehicles

Figure D-7. Live-load Moment for Tracked Vehicles

Figure D-8. Live-load Shear for Wheeled Vehicles

Figure D-9. Live-load Shear for Tracked Vehicles